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POWER FOR PROFIT

PRINCIPLES GOVERNING THE USE OF MACHINERY AND LABOR IN MODERN BUILDINGS

BY

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NEW YORK
THE DE VINNE PRESS
1915

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CHAPTER I

COUNTING THE COST

Owning and operating machinery is not a direct advantage to real estate

COUNTING THE COST

THE purpose of this book is to aid owners of real estate by placing clearly before them the principles which affect the investment of their money in an important element of income-producing property, namely, the services which are involved in the conduct of modern buildings, and the operation of heat and power generating machinery.

The investor in improved real estate acquires with it certain obligations as to the maintenance of services of a very necessary character, but is also frequently involved in providing other services which are not wholly necessary, but are of the nature of conveniences. Both of these, and especially the latter, are often of unnecessary extent, or are of such a character that their cost burdens the property to its disadvantage. The wasteful habits of tenants and the demands of occupants thus combine to render the operation of some buildings so expensive as to make the investment less remunerative than it should be.

A form of relief which is sometimes sought is in the direction of so-called "higher efficiency" of apparatus, involving refinements or complexities added to the operation of machinery, rather than in the direction of attacking the difficulty at the source of the demand, by the possible reduction of requirements, or by economical readjustments which may reduce rather than increase the extent of machinery and labor.

The installation of mechanical appliances in modern buildings now involves a substantial proportion of the original cost, and their operation forms a considerable part of the annual expense, and also requires a major proportion of the care. The circumstances under which such machinery is installed and operated, the financial elements and the contingent expenses thereof, the accompanying increase in the employment of labor thereon, and the consideration of means of so modifying these conditions as to afford financial relief to buildings, are matters which directly affect the investments of individual owners, and have an important bearing on the value of improved real estate as a form of investment.

The business of owning and of operating machinery does not appear to be in itself of any direct advantage to the ownership of real estate, but is rather of the nature of an accessory burden. The less responsibility that is involved, the less detailed care and concern that is required, and the less risk of contingent loss, the more attractive becomes the ownership of such property.

It becomes apparent, upon consideration of the past history of real estate, that modern inventions and habits have gradually fastened upon its ownership burdens from which, until recent times, landlords and lessees were free.

By the introduction of these burdens, and their accompaniments of machinery, buildings have been made not only more expensive to construct, but an increased extent of building construction has been involved in order to house the conveniences and appliances, and thereafter continuous expenses are involved in the management and maintenance of machinery; and, to crown the whole, an additional taxable value is created.

The general effect of the introduction of machinery into private property has not been wholly fortunate. Landlords have been driven, by the force of competition of other buildings, to concede to their tenants a number of expensive conveniences in the form of free heating, free lighting, free power, free elevator operations, free refrigeration, and other gratuitous services, some or all of which could be obtained by the tenants direct, or might be paid for as and when enjoyed. This has been done, often, in spite of the fact that meantime, to meet the very needs thus created, public systems of service have been developed, seeking the business which is being conducted on their own responsibility by landlords.

Modern inventions and habits have fastened new burdens upon ownership of real estate

Whether the owner of a building now receives in the rental a commensurate return from each beneficiary of these gratuitous services is not always clear. Even when payment is included in a rental, whether each individual tenant pays the due proportion of the expense of the service he enjoys is still more dubious.

The point would be very clear, and easily ascertainable, if it were not for the fact that some services are common necessaries involved by modern methods of building. Elevator service is a necessary accompaniment of the high building, though even that simple proposition is clouded by the fact that elevators are of little or no use to tenants of lower floors, who, nevertheless, may be paying in rental a share of their cost of installation and operation. Such services as elevators, sanitation and heating may thus be an unavoidable burden upon real estate, but the creation of the energy or the heat which they involve is not of necessity of the same character.

Where any means is available for relieving the operation of a building of the care, and its ownership of the responsibility of producing power, steam, water, electricity, gas or refrigeration, it would seem, especially in view of the constantly reducing scale of the prices of public supplies of those services, that it is as much the duty of any one advising an investment, as it is an exercise of common sense on the part of an investor, to weigh the circumstances before installing machinery for any or all of these purposes, rather than to sink money in an investment which may be liable to disturbance of its value in the not distant future. If machinery has been already purchased, it becomes equally advisable from time to time to reconsider the necessity for and value of its operation and product.

Owners of commercial and residential buildings which may be operated on rather narrow margins of profit, when they happen to be confronted with reductions in rentals, or increasing vacancies, due to overproduction of space in other and newer buildings, or to changes in value due to local conditions, are often confused as to the conditions in which they find themselves as regards operating expenses and as to any remedy therefor. Careful consideration of operating costs, and of the bearing of contingent costs thereon, is then desirable.

Their confusion is not lessened by the arguments of ardent advocates of the virtues of machinery, often influenced by the desire to effect a sale of some newer and perhaps more efficient form of apparatus. The vision of the true cost of household machinery, however, cannot be secured from the point of view of one part of the appliances installed, which must be examined in the light of the effects of combinations of the services rendered. Combinations of service are not confined to a single set of circumstances, but are generally capable of modification by different methods or alternative systems of supply.

The fact that a certain set of conditions in a building has been adopted and set in operation does not preclude the possibility of an equally good, if not better, result by some remodeling of the conditions to suit another system of operation. The weakest element in all modern machinery is its rapid supersession not only by some other form of its own class, but by the change of methods in other directions, which renders its functions useless or its output commercially worthless. It is not only that machines become antiquated, but that the process to which they are applied may become obsolete, which makes the investment in machinery a possibly dubious investment, where positive necessity or a trade process does not necessitate its adoption.

There is no commercial value in machinery, the output of which can be purchased at the same cost

These considerations apply particularly to city conditions, in which changes develop more rapidly than in country places. Moreover, in cities systems of public service come rapidly into being, and as they extend so reduce the cost of their product as to compete with that of independent units, gradually rendering their output commercially valueless. Thus every successful public demand for the reduction of the cost of electricity, steam or gas spells the destruction of the commercial value of some private apparatus. The process is so well appreciated by some of those whose interests it affects, that strenuous efforts have been made in some cases to secure the increase of the price of public service to large consumers, while effecting a nominal reduction to the smallest class who cannot use power-generating machinery. This was a course as unjustifiable as would be an attempt to make a railroad charge for carload freight the same price as for the carriage of an express package.

There is no commercial value in machinery the output of which can be purchased at the same cost, with the same degree of convenience. Machinery, once installed, though at the time it may be effecting a demonstrable saving over the then cost of operation by some other method, is often found to be operating at a loss unless continual observation be directed to the recomparison of the subject. Since the costs of operating private machinery must always be on the increase, while the prices of public services must always tend to decrease, the two are always proceeding towards the point where the value of private machinery disappears.

This is reached sooner than the mere comparison of unit costs of a single service would indicate. For instance, the unit cost of a private production of steam might be as low as that of a purchased supply, or even lower; but taken in conjunction with a lessened cost of some other service which may result from its adoption, it might prove cheaper to abandon the local production of steam and purchase the supply.

The loss upon machinery, the value of which has been discounted by competition, is almost total. A building is not necessarily injured in value by change of occupation, but machinery becomes of only second-hand value the day it begins to operate, and upon discontinuance has no more than a scrap value.

The returns from a building may suffice to produce a proper return upon the capital but for one or other element in the cost of operation. Anything that trenches upon that net return which provides adequate interest upon the capital, reduces the capital value. The investment requires a certain proportion of net income to maintain a given rate of interest, and any unnecessary feature of its operation, the cost of which reduces that available proportion, cuts into the interest, with the result that the capital value is proportionately reduced.

Even so small a matter as a single minor convenience in a building may have a disastrous effect upon the whole investment. The provision of telephone service in small apartment houses has long been a source of loss to their proprietors. Owners of an extensive amount of such property have often lost thousands of dollars annually by this service, reducing their profits to that extent. In smaller properties the capital value has been affected. In a twenty-family apartment house, the deficiency between the contract obligation and the revenue collectible from tenants for messages is often as much as ten dollars per annum per apartment. This may reduce the return upon the investment of the owner, which is usually an equity, so as to reduce substantially the whole saleable value of the property.

A single minor convenience in a building may have a disastrous effect upon the whole investment

The installation of manufacturing machinery for the production of steam or electricity is always predicated upon either the absence of any other means of securing the same services from any other source, or upon the assumption that its operation will be at less cost than a supply purchased from some exterior system, or produced by some other method on the premises. In other words, its commercial value is always bounded by comparison with other means of accomplishing the same object. The part of the adviser in such investments should always be to weigh these comparisons without prejudice, to insist upon including every proper element, not only of direct comparison, but those bearing on the substitution of other means or methods. In particular, professional ethics demand that without regard to pecuniary loss or additional labor to himself, the advising engineer should endeavor to avoid, for his client's interest, any unnecessary expenditures upon engineering constructions. The engineer's duties are essentially those of forecast and prevision, of clear understanding, of unbiassed weighing of present and future contingencies. If by such methods the client is relieved of capital or current expenditures, the engineer's service has been the greater. And in the correction of deficiencies already involved, the engineer's service resembles that of the surgeon cutting out a detrimental element where necessary to the future well-being of the patient.

The engineer's familiarity with machinery should not lead him to ignore any elements of risk, doubt or danger, either physical or financial, but rather to emphasize them to those owners of property whose unfamiliarity with technicalities may lead to an undue confidence in their own ability to master and control them.

That lawyer serves his client best who brings before him the full risks and contingencies involved in a suit, and urges consideration of every possible means of avoidance of the use of legal services. Similarly, it is not the whole duty of professional engineers to design and install machinery, but just as properly to decide against its use where the circumstances warrant, or where future risk to the purchaser is involved.

Engineering practice now involves, and to an increasing extent, the study of those financial problems which affect works of a technical character.

The existence and continuance in operation of plants of power and heat apparatus in many successful buildings may be considered as a general justification of the system of private operation. Those plants may at once be excluded from consideration of competitive economy with any public source of supply when no system is available for an alternative method of service. But even where this is the case, it is desirable that alternative methods of interior operation should from time to time be considered, and that careful examination of existing wastages of the products of the plant be made.

Any unnecessary use of the output of power or heat machinery has the deceptive appearance of economy, by giving the effect of a low unit cost, or by spreading the total cost over a larger number of pounds of steam or other division of the product.

The real value of the operation of the plant is confined to the necessary requirements of service, to the economical use of energy or heat, and to the net utilized product exclusive of any part which is absorbed by the machinery or the labor attendant thereon.

The net product of machinery is that which would be required to be provided, in its absence, by some other source of supply. The economical utilization of the net product determines the value of the work of the machinery.

Wherever an opportunity exists for the purchase of services from outside sources, these plants must be justifying their existence and continuance, by some lessened cost as compared with the price of equivalent net service economically utilized.

Unnecessary use of the output of machinery gives the deceptive effect of economy, by giving a low unit cost

The nature and extent of competitive service has been a subject of much discussion by advocates and opponents of the private operation of machinery. It is unfortunate that in nearly all cases the question is involved in assumptions, which often leave the owner of the property in a state of uncertainty.

The facts and considerations upon which such comparisons are or should be based are not readily available to those most interested in them. The purpose of this work is to afford such information, to define the fundamental principles involved, and to apply to them the result of practical experience and observation.

There is naturally a great diversity in the conditions under which privately-owned machinery is operated. There is equal diversity in the character of the machinery employed. It must be admitted that while principles may govern and should direct the policy of employing machinery, closely-detailed investigation must be applied to individual circumstances to ascertain their bearing and effect.

The subject takes in two phases: that of the establishment of machinery where none exists, and that of apparatus already in operation. In the former case capital has not been sunk, in the latter the money has been spent and cannot be recovered. In both circumstances a careful weighing of the fundamental features which are involved must be helpful.

Comparisons or recastings of the operation of isolated power-plants with some other system of operation, such as the public supply of energy, are often made to appear to the disadvantage of the latter, by assuming that existing conditions and extent of labor cannot be changed.

Sometimes the assumption is made that necessary attention to other machinery, in the absence of electrical generating apparatus, will demand the continued care and attention of the same class and extent of labor as that in attendance on generating apparatus. It is, upon such assumptions, rather too easy to predicate an unduly low cost of the energy generated by a plant, because its whole cost appears to be only that represented by the fuel consumption directly attributable to its generation, and little or no labor is involved in its production.

It is very easy to dispose of a matter in this manner, but the result is inconclusive. It does not follow that any condition in a plant is necessarily of a fixed character. Labor is often found to be of an unnecessary extent, a growth of an insensible nature based perhaps on an uneconomical condition of operation.

Labor must, if true economy is to be considered, be reproportioned to any change in operating conditions. The operation of a plant in night hours may perhaps be a necessity, but with a public supply night service can be dispensed with. Steam-operated machinery generally requires more supervising care and attention than does electrically-operated apparatus.

Judgment and common sense are required in readjusting labor to changed conditions. The services of a man cannot be cut in two, but of two men one can be dispensed with, or one man may be employed during a shorter period of the year.

CHAPTER II

POWER AND THE MAN

Labor becomes a primary consideration in the production of heat or power or light

POWER AND THE MAN

THE use of machinery always involves the employment of labor, and the cost of labor is usually the largest element in the expense of the operation of small machinery. Labor, therefore, becomes a primary consideration, particularly in the production of energy in the form of heat or power or light.

The conveniences of modern existence largely depend upon the use of power or heat, and the advances of scientific knowledge have rendered generally available the generation and distribution of energy by convenient and accessible methods. The use of energy, in various mechanical or electrical forms, has therefore enormously increased, and now affects, in one way or another, the personal convenience of people of almost every class, under whatever conditions they may be existing.

The forces of nature are the basis of all available mechanical energy, and these exist in various natural and physical conditions, some of which, however, the mechanical arts have not yet rendered commercially utilizable. The most abundant and wide-spread forms of natural energy, such as the rays of the sun, the movement of the atmosphere, and the flow of tides, have been utilized only to a restricted extent in practical mechanical apparatus. If the sun heat and wind motion could be extensively utilized, then every locality and individual property, however small its requirements, might be provided with heat and power from these unfailing though intermittent sources.

It is, of course, probable that as time proceeds the development of science will lead to the utilization of such universally available sources of energy as the rays of the sun, but at the present time the progress of mechanical science is at the point where general dependence has to be placed upon natural materials which are readily available and can be transported conveniently to places where the development of heat and generation of energy are desired to supply the now numerous processes in which these elements contribute to the convenience, necessities and profit of the population of civilized countries.

From a practical point of view, the general necessities of modern communities are dependent upon the use of natural combustible materials, which exist in many forms, but the most convenient and accessible of which consists of coal, the value and cost of obtaining which material, therefore, lie at the base of the main usages of heat and energy of the present time. The cost of the material is not fixed. Natural conditions involve its gradual increase.

The extent of the ultimate coal resources of all countries has become a subject of international interest. The amount eventually available can at present only be estimated, and future explorations and greater knowledge of subterranean deposits may demonstrate the existence of still larger quantities, but at greater distances from the surface and from the present centres of population.

Of all fixed deposits of a mineral character, including gas and oil, an eventual though remote exhaustion must be conceded. The latest estimate upon available coal deposits in this country is six hundred thousand millions of tons, which is probably as good a guess as prior efforts on the part of official statisticians.

It makes no distinction between the quantity of deposited material and the portions which can be extracted, and of possible improvements in the methods of extraction which are capa-

All mechanical operations involve expenditure of human energy

ble of improvement, and are at the present time undergoing a course of development. Nor does such a rough estimate of volume take account of the character and relative value of the fuel, nor does it include the available deposits of lignite, having a heat value not far removed from that of coal. For what it is worth, this latest guess places the point of exhaustion of supply, based on the present rate of extraction, at about twelve hundred years.

The fact has been widely utilized by the advocates of conservation of natural resources to support a theory that the immediate development and operation of water-powers should be undertaken as a source of conservation of the supply of fuel. The theory is erroneous, since the displacement of the present use of fuel by water-power or other continuous sources of energy does not evade the eventual use of any fuel, but merely postpones the time of its ultimate utilization. When that occasion is reached the continuous power of water must be assumed to be just as available as it is at present, and will perhaps be more economically justifiable than is the case at present, with the present readily available and cheap supplies of fixed fuel. Moreover, the developments of the future may bring about the provision of other forms of fuel, such as vegetable growth, which may be made automatically replenishing.

The powers of falling waters are limited in value by their fixed location, but are extensively utilized by modernized methods, by which their energy is transformed into an electric form, and is adaptable to transmission to considerable distances. But the process is bounded by the cost of the installation and apparatus, which restricts its commercial value, and by the necessary combination of a fixed locality for the power-generating plant with the proper and convenient utilization of its product. It is usually necessary to separate the two and provide for transmission of energy.

As in the case of all other mechanical operations, the development of natural energy, or even the acquisition of a fuel, as well as the transformation of either into some utilizable form, always involves a certain expenditure of human energy, which is required to be exercised in some manner in connection with or in directing the operation of the forces set in motion or utilized. Human energy is in itself, so long as the race shall endure, an unfailing source of mechanical power, more continuously available than the heat of the sun, but it is of restricted capacity. The value of human labor, however, is the basis for the comparative value of all other forces. Malthus suggested that the basic unit for the scale of comparison of the value of all articles at any given time was not monetary, which is, after all, only a fictitious standard, but that of "a day's labour of an agricultural labourer." This labor is the basic source of natural wealth, and its value in support of human existence mainly consists in what it can produce out of the soil. But its value is discounted, as Babbage later pointed out, by the cost of its upkeep, or necessary food, which is a part of its product consumed to maintain it in operation. Monetary value may be added by additional demand, or by the relation of the product to general necessities.

From a practical standpoint, only where its superabundance and cheapness of support, as in undeveloped countries, are a prevailing condition, can the labor of man be economically applied to provide or supplement energy derivable through mechanical methods. From an economic point of view, therefore, it must always remain a problem to what limited extent human energy can be employed in connection with the development or use of power, since all the forces of nature are, in point of fact, additions to human energy. Man is a portable heat-engine, the most marvellous combination of flexible mechanical utilization of energy produced by heat. The useful effect of a man's mere

Man is a portable heat-engine, the most marvellous combination of flexible utilization of energy

muscular energy is greater than an equal amount of any mechanically developed force, by reason of its greater flexibility and portability. But its value is vastly greater because of its adaptability to circumstances by the reasoning capacity of the brain. Unless this capacity be fully utilized, the value of human energy is wasted, for it is capable of producing larger effects in directing the operations of other means of power than in directing the single organism to which it belongs.

The maximum mechanical force of a man is but a twelfth part of a mechanical horse-power in lifting operations, and then only for a limited period of time. It is about a fifth of that of the power of a good horse in hauling loads horizontally. The man, even in agricultural pursuits, thus becomes economically the director of animal power, and in place of hauling at the wagon directs the exertions of the team. He usually directs the operations as a part of the load carried, and in this situation his weight becomes a part of the work to be done, so that the net value of the animal's energy is discounted by the carriage of the weight of the man. Its monetary value is reduced by the cost of his food and sustenance added to that of the animal. Economy, however, results by the utilization of the man's special powers of flexible movement and mental capacity in directing the efforts of the animal. The greater the number of units in the team, the less is the relative cost of this direction, and the cheaper becomes the total output of the combination.

This principle applies whether human energy be occupied in actual manual labor, such as lifting coal and ashes, in operating tools or mechanisms, or even in directing and supervising the operations of other less skilled labor or of automatic machinery. The cost value of labor should be proportioned to that of its product, for if the cost of the human energy employed in or about the development of a product becomes the largest single element in the total cost, the balance of values is on the wrong side. Too great a dependence is then being placed upon the weakest part of the combination; that is, too much is being done by mechanical use of human energy, which could be better employed in aiding or directing a larger process.

The progress of economic production during the age of mechanical developments has been always towards supplanting muscular effort by mechanical force. This process is due to the value of human time, the main limitation of the energy of the race. The sum of each human being's contributions to the world's progress and wealth is limited by fatigue, age, and death. The principle of the division of labor, which the advance of man's intelligence has developed, and upon which his present welfare is based, is a necessary outcome of the fundamental requirement of the utilization of the limited time of each individual, and this applies as much to his mental as to his muscular capacities.

The process may eventually eliminate human muscular labor entirely; but even if that be the outcome, mechanical appliances will demand an increasing degree of attendance, and particularly of intelligent supervision proportioned to their greater degree of complexity. The fact that an automatic apparatus can be made to perform functions previously exercised by a number of human hands, guided by the exertion of human intelligence, is always accompanied by a necessity for placing such an apparatus in the charge of skilled operators working under the direction of intelligent supervision, and also for maintaining it in operating condition by the employment of skilled mechanics. The economic value of the apparatus is, therefore, always modified by the additional amount required to be paid for the higher order of labor involved in its operation.

Not only is labor so employed of greater commercial value, but, as Babbage says, "the ultimate consequence of improve-

Greater production means greater return in wages, collectively and individually

ments in machinery is almost invariably to cause a greater demand for labour." This economic process has followed the advance of mechanical improvements into every form of utilization, with the result that both the volume and the rate of wages earned by labor have not receded, but have advanced with the progress of mechanical improvements.

The economic conditions accompanying all mechanical improvements necessitate the gradual increase of the size or number of apparatus, and of their output relative to the amount of labor employed in connection with them. The increased skill or the intelligence of the worker involves their application to a larger output, for the production of the increased volume, or the greater value of the product commensurate with the proper remuneration for the worker. Greater production brings a greater return in wages. The process is inevitable, and its progress can be read in detail in the development of the work of the individual manufactory, or in the gross results recorded in the statistics of the Census. In our country in 1904, five and one-half millions of wage-earners, aided by 2.47 horse-power of engines per worker, earned three thousand one hundred and eighty-four millions of dollars ($3,184,000,000) and added three thousand one hundred and nine millions ($3,109,000,000) to the value of the materials they used. In 1910, six and six-tenths millions of workers, aided by 2.82 horse-power of engines per worker, earned four thousand three hundred and sixty-five millions of dollars ($4,365,000,000) and added four thousand one hundred and sixty-six millions ($4,166,000,000) to the value of the materials they used.

The relation of labor earnings to the cost of materials was decreased from 37.4 per cent. in 1904 to 36 per cent. in 1910. Yet the rate of wages per worker rose 13.7 per cent., and the total wages earned rose 40 per cent.

This point may well be illustrated by the progress of methods of feeding fuel under steam-boilers, which underlies most of the modern commercial processes in which human labor is engaged. Muscular effort is still largely utilized in lifting the fuel and in stirring and cleaning the furnaces. If the proportion of the value of the labor to that of the fuel becomes too high, it is evident that the labor is less effectively employed than it is capable of being. The process involves only a limited exercise of intelligence, compared with the degree of muscular effort required, and the intelligence would be better employed in directing mechanical operation of the force required.

The increasing size of steam-generating plants necessitated improvements in such conditions, and automatic stokers and other appliances for feeding the fuel without any muscular effort have been developed. These require a less exertion of actual energy, but demand the exercise of a higher degree of intelligence in their control, which therefore warrants a higher rate of remuneration. This process has proceeded so far as the development of enormous boilers in which one man may control an output of five thousand boiler horse-power, or sufficient to operate an engine of ten thousand kilowatts of electrical capacity.

CHAPTER III

LABOR RELATED TO POWER

Labor is often found to be of an unnecessary extent, a growth of an insensible nature

LABOR RELATED TO POWER

IN the production of heat or the generation of power some exertion of human effort is always necessary. Where automatic apparatus is employed, this effort is greatly reduced, and becomes in great power-generating plants mostly of an attendant character, manual labor being exerted only in repairing, oiling, adjusting or observing the operation of the appliances. In the process of domestic production, only in the case of unusually large installations favorably situated is such complete automatic operation possible. The great majority of domestic apparatus require the exertion of actual physical labor in the operation of handling coal and ashes, or in cleaning and adjusting fires in steam-boilers.

The relation of the cost of this labor to the fuel becomes an important consideration in comparing the value of other forms of fuel, such as oil or gas, the use of which involves no actual effort, but may require a higher degree of intelligent direction and more concentrated attention.

Labor required in connection with the operation of motive apparatus, such as engines and pumps, is always paid higher rates than labor exerted in fire-rooms, and this in spite of the fact that the latter is engaged in an operation requiring hard labor, and also involving the economy or waste of a valuable commodity.

This established system is, however, the logical result of the economic law previously described, whereby labor, disengaged from actual effort, is more advantageously employed in the direction of power-operated apparatus, and can thereby earn a higher rate of wages. This process may, in the case of fuel-firing, have proceeded along these lines too far, since the application of greater skill and higher intelligence to the processes of fuel consumption should entitle the attendants of boilers and kindred apparatus to higher remuneration, for their efforts are capable of effecting direct economy in the use of a costly material.

In the same way very complex appliances are sometimes utilized for the purpose of producing a high degree of economy in the use of steam, oil, or gas in engine and pumps, while similar expenditures are not made in the direction of economy at the source of energy production—that is, in the character and use of fuel.

Refinements of efficiency in machinery always carry with them some increase in attendance, or skill in operation, involving additional expense for labor, which tends to discount the financial result. The comparative value of investment at the source of production of energy should be weighed against the net value of refinements in operating machinery. Thus it is very frequently the case that steam-boilers are placed in disadvantageous positions which involve some otherwise unnecessary labor in fuel-handling, or some disabilities in draft and air, which situation has been brought about for the purpose of affording facilities and conveniences around power machinery, the beneficial effect of which cannot offset the continuing losses in the fire-room.

In domestic installations the most defective element is generally the emplacement and conditions of steam-generating apparatus. As steam-boilers are of very varied design and characteristics, it is not too much to say that there is for every particular available space and condition of access and draft one suitable type of boiler best adaptable to the circumstances. Lack of appreciation of this limitation tends to the deficient character of the majority of steam-boiler installations in domestic service, with the accompaniment of much ineffective labor at unnecessary expense.

Refinements of efficiency in machinery involve increased cost for attendance or skill

The natural trend of economic production, which applies to the production of power as much as to any other commodity, is in the direction of accomplishing with any given expenditure of human energy, whether muscular or mental, the greatest possible relative output, a process equally as desirable for the worker as for the employer. Unfortunately, this process too often appears to the wage-earner as directed towards securing the greatest possible extent and value of output at the expense of the wage-earning class, by reductions in the total labor employed. So against the irresistible force of economics are often arrayed the actions and opinions of wage-earners who find from time to time that their labor, in its present form and with its existing requirements of intelligence, is discounted in value, and sometimes actually discarded, by the increased output of other workers in combination with larger machinery. Such changes certainly do reduce, though only for the time being, the opportunities for the use of labor in its existing condition.

Such effects led to a similar attitude on the part of wage-earners, exhibited towards nearly all mechanical adaptations to processes previously conducted solely by muscular effort, as in the case of the blind rage of the weavers of Lancashire and Nottingham in the destruction of new inventions which appeared to them at the time to menace their means of employment and subsistence. An extreme result was the stipulation in the franchise of an English canal, that only human labor should be employed to haul vessels upon its waters.

To-day the same process of misunderstanding is evident in the hostile attitude of certain organizations of workers, who are engaged in the operation of small power-producing apparatus, towards the concentration of the manufacture of energy in large power-stations, and its public distribution, in competition with its production in small quantities in household installations of machinery, which have come to be commonly known as "isolated plants."

The statistics of the National Census upon the commercial electric light and power industry demonstrate the fact that these are baseless conclusions, for labor benefits collectively and individually by the concentration and increase of production.

In 1902, 30,326 employes in 3,620 electric light and power systems earned $680 each, while ten years later the number of employes had increased 160 per cent., to a total of 79,335, engaged in 5,221 systems, and the average earnings were $770, an increase of 13 per cent. per annum.

In 28,005 commercial electrical stations which increased 30.4 per cent. in number, the power of the machinery, during these ten years, was increased 333 per cent., and the total output 375 per cent. The cost for wages per kilowatt-hour of output was reduced from 1.32 cents to .55 of a cent, and the average price at which the product was sold was also reduced from 3.33 cents to 2.4 cents, or 30 per cent., but all of this was accompanied by an increase in the individual earnings of labor.

The misunderstanding of this economic process has led to considerable misrepresentation in various publications, which have pictured it as a struggle between Power and the Man. The advocacy of isolated plant operation, based thereon, has nowhere shown more marked and interesting developments than in the City of New York. The situation in that metropolis involves some features which are not evident to an equal extent in other localities, and therefore present a favorable opportunity for consideration of the essential elements of the problem.

The efforts of wage-earners have been naturally directed not

Unless the output of machinery be increased, the product is always increasing in cost

only towards a reduction in their hours of labor, but an increase in their remuneration.

They cannot be expected to remain satisfied with a stationary rate of wages, even if a reduction be made in their actual work.

The natural decrease in the purchasing or exchanging value of money requires that human labor shall receive more money for equal effort.

In this regard, human labor differs from commodities and materials, the increasing money value of which may be, and generally is, offset by more efficient methods of production.

Human labor cannot be reduced in value by efficient methods, but is, on the contrary, increased. Even an individual worker in an operation of so limited a scope as a private steam or electric plant, is entitled to the progressive money value of his labor.

The result is a progressive increase in the cost of the labor element in the operation of private power-plants. This is adverse to the economy of such installations, for their cost of labor is always relatively greater than it is in large combinations, and is often the largest single item of expenditure. Accompanied by an increasing cost of fuel and of other items of expense, such as repair, the process becomes one of financial deterioration of such installations, gradually increasing the cost of their operation towards some point where the substitution of other methods, or the use of appliances with lessened labor, would represent equivalent results at less cost. This must inevitably be the case in any operation the output of which cannot be increased proportionately to meet increasing expenses. Unless the output of machinery be increased, the product is always increasing in cost.

While the progress of economic development has proceeded on such clearly defined lines in industrial and commercial operations, similar processes conducted under governmental, and particularly under municipal, auspices always have lagged and apparently must continue to lag behind the march of economic commercial progress. This is due to the underlying influence upon the economic processes of the lack of specialized training of officials controlling the operation of public affairs, and also to the consideration which must be accorded to the opinions and feelings of the general public, who are not always fully informed upon economic subjects. As in the past, it seems to be still a prevalent conception of governmental operations that they shall employ as much as possible of human labor. Humane public opinion also supports the principle that such labor shall be exercised under conditions not less favorable than those in the most advantageous commercial operations, and shall be paid the highest average rate of remuneration, and shall, moreover, receive liberal compensation, in addition to payment for services directly rendered, by provision for pensions after the period of active service has passed. All these involve a larger extent of labor for any given process than equivalent commercial operation requires.

Nor is it to be considered a necessary feature of municipal employment that the employe shall be fully competent. The employment of veterans, or of aged or even incompetent labor, is a frequent and proper occurrence. It is justifiable from the point of propriety, and in certain classes of duty around machinery it presents little financial disadvantage; but in a fireroom such a form of labor is disadvantageous from a pecuniary standpoint, for in such employment incompetence is applied to the consumption of a valuable commodity. Unintelligent labor, therefore, if maintained for any reason, should be employed on any line of work rather than the handling of fuel or the operation of machinery involving possible waste of energy.

The result of these circumstances is to render operations of the nature of the manufacture or use of power, when conducted

Unintelligent labor should be employed on any line of work rather than the handling of fuel

under governmental auspices, relatively expensive in the proportion which the cost and value of labor bear to the product. It is unfortunately noticeable in municipal affairs that a sense of responsibility for the return to the employing agency of a full value in labor for the remuneration received is not a marked characteristic of some employes. This is perhaps due to a usual lack of inducements towards personal initiative, and accompanying or resulting failure of interest in prospective developments of the operations in which such employes are engaged.

The methods necessarily employed in the selection of employes through the restrictions of the civil service system also account for inefficiency in some official employes, and for a certain reluctance on the part of many energetic, active and interested personalities to enter that field of service. The recognition of these circumstances does not by any means preclude the concession that in such employment are many skilled, competent and intelligent persons, but under the methods and systems described they must nevertheless be limited in the work which they might accomplish by the conditions obtaining in their sphere of service, which they must often share with others less interested or active. Political influences too often control the effectiveness of labor.

Under municipal operation the officials in charge of a power-plant may discharge incompetent workmen in an effort to secure a proper amount and intelligent degree of service, but will soon find that the same men are reinstated by outside influences, or by the operation of civil service regulations. Officials are sometimes subjected to much pressure, which they are ill situated to resist, in such matters, and their prevailing attitude is an obligation of the municipality towards the labor in its employment, rather than an obligation on the part of labor towards the public organization.

Independently of economic causes, labor becomes entitled to higher wages as time proceeds, as it becomes more intelligent, capable or experienced.

In connection with the operation of mechanical appliances for the generation and use of energy, modern developments have generally been in the direction of greater complexity, requiring greater intelligence or skill in direction. In the generation and disposition of power, such developments have tended largely towards the general utilization of electric apparatus, much of which involves a high degree of knowledge and skill. These afford means of utilizing the increasing experience, intelligence and knowledge of men employed.

The process therefore indicates clearly the line of future advantageous employment of the class of labor employed about domestic plants, namely, by their arming themselves with a greater degree of knowledge upon the subjects referred to, especially as regards the economic utilization of energy and the reduction of cost in the operation of power appliances. Operatives whose services may apparently be disturbed by the introduction of automatic machinery, or by modernized combinations, or by the utilization of public services of gas, electricity, air, water, ice, oil, or steam, will find opportunities for their services increased rather than diminished if they become adapted to the situation and prepare themselves for the economic solution of new problems. To sit back and oppose the substitution of more economic methods and less costly combinations, as has been the attitude, to some extent, of some of those engaged in operating machinery, is a reversion, by a class of highly intelligent men, to methods such as that of the workmen of bygone times, before whom "Kay of the fly-shuttle, Hargreaves of the spinning-jenny, and Arkwright of the spinning-frame, all had to fly, glad to escape with their lives."

Labor employed in the actual consumption of a valuable com-

Negligence of employers is usually exhibited in respect of the burning of fuel

modity, such as fuel, should be valuable in proportion to its intelligence and experience. The fireman who, with advancing years, may be unable to handle the weight of fuel which he could readily manipulate in his younger days, may nevertheless be of increasing value to his employer if his advancing years have brought additional experience and relatively increased alertness in adapting himself to improved methods and in promoting the more economical consumption of fuel.

It is unfortunate that this particular kind of improvement is rarely to be found, and this is perhaps due more to negligence of employers—which, strange to say, is usually exhibited in respect of the burning of fuel—than to any unwillingness on the part of firemen. It has been one of the interesting economic results of the operation of large power-producing companies, that the closest attention is given to economies in fuel consumption. These have largely been brought about by the substitution of mechanical firing for manual labor, but an advance in the commercial value of the fireman has followed the introduction of such machinery.

Even though automatic machinery actually eliminates the work of the fireman by displacing the handling of fuel, it remains a fact that the firemen in attendance upon automatic stoking appliances receive better wages than when engaged in the manual labor of shoveling coal. A pronounced instance of an up-to-date character is found in the great boiler-plants of central stations, where the operation without any manual labor other than the control of levers, but by the intelligent use of scientific appliances placed at the fireman's command, produces the most economical results so far attained.

Men so engaged are directing the operations of appliances which perform the labor that would have to be done by many other men, but are themselves receiving a much higher rate of wages than they could possibly have obtained as one of those engaged in mere manual operations. The question may naturally arise as to the other men whose labor is apparently displaced by the machinery. The answer is, of course, that as a matter of fact they are not so displaced, because these machines could not possibly have been handled by hand labor, and are constructed for their existing duty with that condition in view. But even had it been so, the employment of men displaced by such enlarged machinery would be found in some other demand for labor created by the output, or brought about as a result of the facilities afforded by the cheaper energy generated in the modernized plant.

The processes of economic change are well illustrated by the statistics of the electrical industry, as reported by the United States Census in a special bulletin issued in the year 1913. The growth of the use of electrical motors in the decade between 1899 and 1909 was as follows: In 1899, 16,891 motors were in operation, aggregating 492,936 horse-power. These had risen in 1909 to 388,854 motors, of an aggregate capacity of 4,817,140 horse-power, an increase of 1,000 per cent. in ten years.

During the same period the average capacity of all electrical generators manufactured had risen from 74 to 112 horse-power, or 50 per cent.

It cannot be doubted that the introduction of this increased use of mechanical power may have had the effect of displacing to some other line of employment a part of the labor previously employed in manual operations; but, on the other hand, the processes in which the increased power was required undoubtedly demanded proportionate employment of labor. In addition, the actual manufacture of these electrical appliances brought about a large increase in the employment of wage-earners in a new line of work; for in the year 1909 no less than 105,600 persons were engaged in the manufacture of electrical apparatus.

CHAPTER IV

PUBLIC SYSTEMS OF SERVICE

The readiness, volume, and equality of character of public services are additions to the value of the product purchased

PUBLIC SYSTEMS OF SERVICE

MODERN developments in the distribution of energy of various characters have brought about conveniences which are utilized in great cities to some extent by practically every individual in the community. This situation is due more to developments in the distribution of energy than in its generation. Facilities for transit by rail or by elevator, the adaptation of gas and steam and electricity to heating, cooking and many minor conveniences, the increase in private lighting and in street lighting, and the many forms in which industrial power operations can be conducted by electrical energy, have built up within each great community large areas over which the public must be served by distributed heat and energy.

The growth of a city is aided by such generally accessible conveniences, and the construction and successful operation of modern buildings are largely a result of the facilities they have rendered available. As the construction of an electric railroad builds up the value of a locality, so the availability of gas, water, steam and electricity makes the occupancy of buildings convenient. Residence, business and manufacturing in any locality are rendered more desirable, and therefore more profitable, by accessible conveniences.

Where the provision of these facilities involves the individual investment in and the individual operation of small centers of production, the advantages are lessened, because the costs are increased; and the natural process of economics has led to the grouping together of consumers on the systems of public service companies, covering large areas, and bringing about the economic condition of increased output relative to the labor employed, which is the governing factor in modern industrial development.

Public systems assume various characters, but always present an element, exterior and additional to the commercial value of their product,—that of superior convenience. The delivery of the product is on a different basis from that of the output of an individual plant or domestic manufacture. The public supply becomes a "service," and its value consists not only in the article or product delivered, but in its ever-present readiness, its extensive volume, and its equality of character. These form additions to the value secured in the mere product, and for such advantages a higher price may be warrantable from an economic or even from a financial standpoint. As the availability of such services is continuous, use may be made of them as and when required, not only as suited to convenience, but as may be dictated by economy in other directions, such as by a reduction of investment or of labor, thus rendering a higher-priced commodity or method of a superior total efficiency and a lessened total expense.

Thus the production of heat in a domestic heater or boiler requires a certain extent of attention, but it may be made automatic and labor may be eliminated when it is operated by a public supply of steam or gas. Such a process, even at a much higher unit-cost for the supply, may be made more economical by what may be called utilization economy, or, in other words, by the avoidance of the wastage which often accompanies intermittent use, and particularly by lessened labor, up-keep and materials.

The use of a house furnace or boiler, for instance, is often continued unnecessarily in warm weather because the process of renewing the fire after it had died out would involve con-

Apparent economy of plants is often based on wasteful conditions of usage of their output

siderably more labor than is available to keep the unnecessary fire going. Moreover, the intermittent cooling and reheating of a boiler, and of its water, setting and pipes, may result in little or no saving of fuel by such action. The cost of the domestic process, therefore, is affected little by care and economy and the prevention of wastage, but all these processes become productive when applied to the use of a public service. With such a service as gas, the facilities for reducing or cutting off the supply when it is not really required involve no effort. The minimum as well as the maximum amount can be burned to advantage. With electrical service, arrangements for ceasing the use of the supply involve no more attention than the pressing of a button or the pulling of a switch; whereas with producing machinery the shutting down of an engine or a boiler involves time and care, and perhaps some losses of material, and a renewal of these on restarting.

The processes of economic utilization of a product therefore differ from those of economic generation of energy. In the case of the latter the chief concern of those in its charge must naturally be in the direction of a low unit-cost of production, the appearance of which is improved by large usage. Since all apparatus gains in economic efficiency by full and continuous demand for its capacity, the larger the output the higher is the efficiency of total production, and the less becomes the relative cost per unit manufactured. In the case of an engine and boiler under continuous full and unvarying demands for their output, higher economy is attainable, per unit of energy developed, than where, as is naturally most often the case, the demand is irregular, or is less than the designed capacity, or is fluctuating in character.

The apparent economy of such plants is often based upon the maintenance of wasteful conditions in the usage of their output. The larger the demand, the better become the apparent operating economies, and the less is the relation of the cost of labor to the unit of output. If the same amount of labor can attend to the production of an increased demand, then the increase appears to be, and often is, of little relative expense; and even if the increase be due to wasteful habits or to inefficient conditions, it is not an object of direct economy to effect a reduction. In fact, such a reduction might require more attention than its monetary worth.

In a large hotel it was observed that the wastage of refrigerating effect and the reckless use of ice were very marked. The doors of kitchen boxes were generally left partly open, others were warped and leaked; ice was drawn when not required, and stored in a warm place, and was left lying about, resulting in much of it merely melting away. The domestic plant which provided this ice and refrigeration was regarded as doing so at no cost, or so little as to be unworthy of consideration because it was operated in part by "exhausted steam."

But so soon as the capacity of the plant became overtaxed, and a supply of ice had to be bought from exterior sources, interest was awakened in the condition of the boxes, and in the wasteful habits of the employes. It may be added that it is doubtful if at any time this plant produced its wasteful output for any less expense than the amount of purchased ice by which the real economical requirements of the service could have been provided.

Economy in utilization, however, in this as in other cases, is frequently discounted by the fact that the plant is established, its operation involves certain labor, and neither more nor less labor would be required if the product had varied. In the case cited the use of heat was partly indirect, and its value or cost was not readily apparent. So everyone contributed to the demand by some form of wastage, which built up a demand which had the appearance of being economically provided.

Economy in utilization is frequently discounted by the fact that a plant is established

It is worth remarking that the promotion of economy and the prevention of wastage in the utilization of a product are quite as much a matter of concern to the business interests of public service corporations as they should be to the owners of private plants. The value of a public system is enhanced by every demonstration of its economic capabilities, and the activities of such companies are thus properly exercised in promoting methods of thrift and economy in the utilization of their products, in educating the consumer to the exercise of care and attention to his own interests, and even in the development of devices designed to economize the use and reduce any wastage of energy. Everything that will tend towards the most effective and economical utilization of a public service is of value to a producing organization, even though the tendency of such methods or apparatus may be towards an actual lessened demand for their product. The promotion of the use of the tungsten filament incandescent lamp is an instance of such action; and though productive of individual reductions in the energy required per lamp, the policy has resulted in a wider and larger total utilization of electric energy.

Just as is the case with domestic apparatus, a public supply of any character competes with an ever present comparative cost of some other method of attaining the same convenience. This limitation therefore operates both ways. It is always the possible alternative means of attaining an equivalent service which controls the value of the output of a private power-plant, as it also limits the price obtainable for a public supply.

The price paid for a public service, however, always includes elements of convenience, extent and readiness which render their supply of a larger value than that produced by an individual method of production. Public systems generally include inherent physical advantages rendering them superior to domestic substitutes. A public water supply is more constant not only in quantity, but in quality, as compared with the water of a domestic well. A public system of distributed brine refrigeration has some fixed advantage over the use of equivalent natural ice, even though the latter may be cheaper; and gas has features which render it more advantageous for certain heating purposes, even at a higher price, than the use of coal. A public system of electric distribution has a special quality of regulated pressure, which is a feature of great commercial value. On the other hand, the production of energy by small generating apparatus is always liable to fluctuations, due to the effect of variations in the supply of its motive energy, as well as in the demand for its output. Such fluctuations would be little felt upon the large units and extensive system of a public supply. The effect of variations of electric pressure upon the life of the delicate filaments of modern incandescent lamps is marked, and their life is shortened thereby. The effects of variation of voltage in motors which operate machinery is to vary the power or speed developed. In the operation of delicate machinery the result may be disadvantageous, or even injurious.

The avoidance of fluctuating demand is a peculiar problem of the domestic plant, and often involves the operation of two generating machines, one serving a fluctuating or power load such as elevators, and another a lighting or other steady service. An alternative method is the addition of a storage battery, involving, however, additional invested capital and some continuous expense in maintenance.

A higher price paid for the publicly-supplied article may be justified by the possibility of its economic combination with other services, resulting in reduction of investment, labor and other costs, and this is therefore a fundamental element in its value; and, as previously indicated, to such economic advantages are added permanence of character, continuance of ready service, and available volume of supply.

As fuel becomes scarcer, public necessity will require limitations upon unnecessary consumption of coal

In another and wider aspect, the extension of public services contributes an indirect value which is shared not only by its consumers, but also by the general public.

Since the producing economies are greater in the larger apparatus of central stations, a relatively less amount of fuel is consumed, for each unit of energy produced, than is the case with the individual domestic plant, in which the destruction of fuel in proportion to the output is approximately four to five times greater, and the diversion of labor from other productive processes is many times as great.

As the resources of the country become more taxed, and fuel becomes scarcer in certain sections, it will probably become a public necessity to place limitations upon any unnecessary consumption of coal, and to require that fuel shall be consumed only at the lowest practicable ratio to the product of its dissipation. Excessive combustion of fuel in domestic plants is brought about by defective boiler conditions, by the inferior economy in operation of the relatively small engines that are necessarily employed, and by the variable character of the demand for their output.

It would be a superior type of small generating machinery in which the consumption of steam per kilowatt-hour of electric energy generated did not exceed three times the rate required in large generating plants of modern type. Taking into account the steam used by necessary auxiliary appliances, and the fixed losses accompanying the irregular operation of domestic plants, it is far more generally the case that the proportion exceeds five times that of good central station power generation.

The fuel consumption in isolated power-plants in New York City is found to be about ten pounds per kilowatt-hour of electrical output. The price of fuel for such purposes is at present from $3.50 to $4.50 per net ton, and the cost of steam only in the domestic production of electricity is as follows:

COST OF STEAM PRODUCTION

Fuel	$3.50	to	$4.50	per	ton of	coal consumed.
Ash removal .	.14	"	.17	"	"	"
Firing labor .	.55	"	.80	"	"	"
Water . . .	.16	"	.24	"	"	"
Boiler up-keep .	.08	"	.11	"	"	"
Totals . .	$4.43	to	$5.82	"	"	"

The cost of steam supply only per kilowatt-hour is therefore from 2.21 cents to 2.91 cents, to which must be added engine-room labor, up-keep and supplies, and fixed and incidental charges.

So long as fuel is accessible and therefore relatively cheap, this disparity will be less apparent than the burden of the excessive proportion of labor. But as time proceeds every element of progress contributes to an increase in cost in both these features of domestic plant operation. The possibilities of commensurate reduction of cost by superior efficiency of apparatus are negatived in domestic operation by the fixed features of the service demands, such as their irregularity and fluctuation, and particularly by their inability to expand the output.

Labor thus engaged upon a limited scope of production is not accomplishing the purpose nor producing the results which it is capable of doing. It approximates the situation of labor employed in muscular operations. It is capable of greater achievements, but is restricted in opportunity for their accomplishment.

The extension of public services, on the other hand, always tends towards reduction in their cost.

The utilization of electrical energy, which dates back only thirty years, has been extraordinarily rapid and extensive, overshadowing and displacing other methods and systems, and proving an exceptional adaptability to a multitude of purposes.

The extension of public services always tends towards reduction in their cost

The accompanying reduction in the cost to the public of electricity has been continuous. In Chicago, since 1886, the average price has been reduced 61½ per cent. Meantime, the improvement in the efficiency of lighting appliances has greatly reduced the amount of energy required for a given result. The combined effect has been that the amount of light purchasable for a dollar has risen from 1,100 candle-hours in 1898 to 9,800 in 1913.

Between the years 1907 and 1912 the use of the carbon form of lamp fell from a proportion of the total in service of 93.27 per cent. to only 25.47 per cent., being displaced to that extent by the metallic filament, chiefly the tungsten lamp. The latter was itself so improved by superior methods that its consumption of energy was reduced 9 per cent. in the same period for an equivalent amount of light.

In those five years the average candle-power of all lamps in use rose from 19 to 29, or over 50 per cent., and the number of lamps in use increased 41.7 per cent., while the cost of the lamps was decreased in even greater proportion.

CHAPTER V

PUBLIC AND DOMESTIC COMPETITION

Every reduction in prices of public services reduces the value of the product of private plants

PUBLIC AND DOMESTIC COMPETITION

The progressive reduction in the cost of public electrical service, and its wide applicability to a large number of operations, together with the progress made in the efficiency of motors and lamps, has brought about a great reduction in the commercial value of combinations of domestic machinery as compared with that which prevailed only a decade ago.

The capital invested in private power-plants may be destroyed by a reduction in the value of the output, since every reduction in the price of public services reduces the value of the commodity which the private plant investment is producing.

A recent reduction in the rates for the supply of electric energy in Manhattan afforded an opportunity of determining the financial effect. In a group of nineteen modern buildings of various characters, having an aggregate installed capacity of 5,640 kilowatts, there is a reduction of the value of their output by $8,600 per annum. This reduction, capitalized at a five-per-cent. rate, is equivalent to a decrease in the invested value of the plants of $30.48 per kilowatt of installed capacity, probably fully one-half of their present value.

The effect of a reduction in demand for the output by appliances or methods having less requirements for energy is also disastrous to capital value in private machinery.

Where power-plants were installed for the purpose of operating lighting installations composed of carbon lamps, an entirely different situation has been brought about by the introduction of the tungsten lamp, affording equivalent and even a superior extent of lighting effect for less than one-half of the energy required by the carbon lamp. Engines installed for this purpose have been deprived of a large part of their load, and their proportions and relations to the other parts of the plant have been radically altered. At the same time, the amount of energy which would be required to be purchased from a public source of supply for the purpose of lighting has been substantially reduced.

The progress of improvement in motor operations, such as the driving of fans, pumps and compressors by electrical motors, has been in the direction of greater economy, and many such appliances could be operated at less cost by electric service than was possible only a few years ago. The operation of such motors can be made practically automatic, controlled by the service required of them, and involving little and intermittent attendance.

A determination to adopt some system or some special appliance, such, for instance, as the "plunger" type of elevator, contributes conditions which may involve the use of power machinery with accompanying labor and costs, to which the addition of electrical generating apparatus becomes an apparently advantageous or even economic appendage.

The views and prejudices of employes often overbalance the judgment of a proprietor in these regards, fastening upon a property an initial economic disadvantage, to which assumable economic additions are excrescences of the nature of increments. Such combinations are of course lacking in total economy, but offer obstructions to a reduction in operating costs by other methods, on account of the expense of effecting changes of one appliance. Apparently economical devices may thus be so in themselves, but not in their effect on the combined plant. Their separated operation may be an apparently insignificant addition to a combination inherently extravagant. A parallel would be the addition of another wife to a polygamous household, which may be an inexpensive or even economical extension of the system, but the total effect of the combination is not the less burdensome on the paterfamilias.

Apparently economical devices may be so in themselves, but not in their effect on a combined plant

The hydraulic elevator is, in itself, an economical apparatus. Its individual operating cost is low, and its up-keep remarkably moderate. But its cost is liable to undue increase by defective pumping apparatus or by intermittent operation. There are plants in which high-class economical pumping-engines are employed, in which a car mile of travel is produced for 220 to 250 pounds weight of steam. But the common form of duplex compound steam-pump is found to require more than three times this amount, and after a period of service the losses due to piston and valve leakage and to short-stroke effects will bring this consumption to as much as 800 pounds of steam per car mile.

But these do not represent the whole expense of operation. The necessity for high-pressure steam for this service in a building involves the continuance of power service, with its labor, space and up-keep, which, if elevators were of the electric type, might be dispensed with.

The hydraulic elevator has little reserve capacity, and if its use is needed intermittently as in night service, steam must be maintained during hours of small demands. The same remarks apply to the steam-elevator, a surprising number of which out-of-date appliances are still in operation.

To change the elevator system to a modernized electrical form often involves considerable expense. A system has recently been developed for utilizing the hydraulic gear and counterweights, and adapting them to the service of an electrical machine, by which means an exchange may be effected with a minimum of disturbance of the existing arrangement and at a moderate outlay of capital.

The improvement of the electrical elevator by the introduction of the traction type has been a marked advance over any previous form of machine for this purpose. The simplicity of this apparatus is now one of its main features of advantage, and its economy has been demonstrated in a marked degree. Elevators are now operated in business building service at as low a consumption of energy as three kilowatt-hours per mile of car travel; and in the case of the newest form of two-to-one traction elevators as low a consumption as 2.7 kilowatt-hours per car mile has been secured. It has been observed that the amount of current used by these machines varies as the number of stops which are made by the car. Where the service is properly apportioned to the requirements, stops or reversals will not exceed four in number to each ten floors in each direction, up and down, which are served by the elevator, and under these circumstances the use of energy will not exceed four kilowatt-hours per car mile.

This result has brought the electrical elevator within the cost of operation of the hydraulic, mainly because of the less amount of labor involved in the management and maintenance of the power-generating appliances.

A rather striking illustration of progress in the electrical direction is that of the adaptation of electrical turbine pumps to the process of pumping out sewage from the lower parts of buildings. The appliances which have been in use for many years are operated by compressed air, which is introduced into the top of a chamber in which the sewage has been allowed to collect, and by its expansive force lifts the material up to the sewer; but the process involves the compression of air, which is usually accomplished by a type of compressing machine which is extremely wasteful of steam. As this apparatus has to be maintained continuously in readiness for emergencies, the cost of operation becomes excessive.

New combinations of existing power machinery may offer opportunities of substantial economy

A test made in a New York hotel, in which the apparatus was newly installed and was in excellent working order, showed that no less than 679 pounds of steam were used to raise sewage to an equivalent extent of one water horse-power. This meant that about eighty pounds of coal were used for one water horse-power.

The electrical turbine pump, applied to the same purpose, effects the result with equal if not superior security, and at much less cost.

Under these changed conditions it will be evident that a reconsideration of combinations of power machinery in the light of existing circumstances may offer opportunities of substantial advantage. This is the more so because, while these processes of economy have been proceeding in the direction of reduction of the costs of public services, and while the producing cost of public service has also been reduced, the corresponding elements entering into the cost of operation of private plants have been in the reverse direction, for coal and labor and materials of all kinds have increased in price.

Such progressive increase is inevitable. The cost of coal increases by reason of the greater expense of extraction from the mine as the process proceeds at greater distance from the surface, involving a larger amount of labor per ton recovered. The rise in price of Pennsylvania anthracite at the mines, in the five years 1908 to 1912, was nine per cent., while the average rise in price of bituminous coal throughout the country was eight per cent. in four years, being an annual increase in cost at the rate of approximately two per cent.

Labor has generally increased in cost. In private employment wages cannot be decreased to meet increasing costs of material, or to suit a lessened extent of output, but is usually increased as the term of service extends, regardless of these conditions.

Under these continuously changing conditions, therefore, in order to establish the current value of a power-plant, a recomparison should be made from time to time of its comparative ability, with these increased costs, to produce results at less than the operation of similar services by purchased supplies of energy or by other means or materials at currently reduced prices. The same extent of service, reduced by any part involved in the operation of the plant, and therefore not required to be purchased, is the net service required to be purchased. If this can be effected at a less total cost by the continuance of the use of the domestic plant, then its continuance is justified, and its value is the capitalized difference in its favor.

If the same effective results can be brought about by other means, at equal cost, the installed plant has only a nominal, perhaps a fictitious value. If the same effective results can be brought about at a less cost than that of the operation of the power-generating plant, then the latter has no commercial value, and it is a waste of human energy to continue its operation.

Public supplies of gas and electricity are now very generally available in urban districts, also supplies of refrigeration in certain places, and to a less extent steam is also available. It does not follow that because one or other element in a combination of appliances can be produced at a less cost than an equivalent purchased service, such a combined operation is thereby rendered justifiable, because a new combination may eliminate other expenses which may reduce the total cost to less than that of the operation of the plant.

Ill-considered legislation sometimes interferes with the process of economics. Gas is almost universally available in modern cities, but its character is largely determined by antiquated legislation, which was founded upon its illuminating capabilities when burned under wasteful and out-of-date conditions.

If the same results can be secured by other means, at equal cost, an installed plant has only a nominal value

The naked fan-tail flame has now been almost completely superseded, and probably less than a twentieth part of illumination by gas is so conducted. Legislative restrictions, however, sometimes preclude the reduction of illuminating enrichment, which is a costly accompaniment of no value in the modern mantle burner or the process of heating and cooking, and thus the reduction of the cost, and therefore the price, of gas is retarded. Public restrictions require continuous modification if they are to meet progressive economic and mechanical developments.

Nevertheless, in New York, in sixty years, gas has been reduced to about eleven per cent. of its original price to the public.

Gas in 1846 was $7.00 per thousand cubic feet.
" " 1852 " 3.00 " " " "
" " 1859 " 2.50 " " " "
" " 1906 " 1.00 " " " "
" after 1906 " .80 " " " "

The application of gas as a fuel for a vast number of purposes is undergoing great extension, and many heat processes long apparently fixed in the use of steam or coal may be reconsidered in the light of present improved methods. The principles of economical utilization apply to services such as gas, water or refrigeration as they do to electricity.

In several foreign cities the distribution of water under high pressure for commercial power purposes has been found successful, both practically and financially.

Hydraulic power has been distributed in the City of Hull since 1878, and in the City of London the system is extensive, serving about seven thousand individual applications, ranging from massive metal presses, elevators and cranes to small suction or "vacuum" sweepers. Its cost of production and distribution is not so economical as that of electricity under modernized conditions, although at its inception it was the cheaper of the two, but it has many useful applications which render it peculiarly valuable, particularly in hoisting machinery and in providing fire protection or "sprinkler" service.

In London the cost of a service of 6,732 horse-power hours in a year is six cents per horse-power hour. Upon the utilization of 16,828 horse-power hours per annum, the rate declines to 5.7 cents per horse-power hour, and additional service thereafter costs only at the rate of 4.3 cents. Thus, a service equivalent to an electrical service of 20,000 kilowatt-hours of energy per year would cost 6.8 cents per kilowatt-hour.

A more expensive material may be more economical when utilized in a more direct manner, and particularly if it is applied with a minimum of labor. Steam-engines are sometimes used to operate machinery because it is assumed that steam is cheaper than electricity. But the electric motor, applied directly to the machine, may greatly reduce the power actually required, and necessitate no attendance.

In comparing the cost of heating by steam with that of gas, the cost of fuel is by no means all the expense involved in the former, as labor, up-keep and fixed charges on investment form a part of the outlay, and several sources of wastage and loss arise in intermittent service. With the use of gas, such expenses and wastages may be greatly reduced. The capital investment in steam-heating apparatus in modern buildings is from one dollar and fifty cents to two dollars per square foot of radiating surface. This is utilized to maximum effort only about eight days in the season, it is in operation only sixty per cent. of the year, and then to only forty per cent. of its capacity, on the average, during the time of use.

The wide-spread use of steam as the means of heating buildings has resulted in the establishment of many public steam-distributing systems in American cities, some of the oldest of which have been in continuous operation for nearly thirty years.

An apparently expensive form of energy may be sometimes the most economical

The prices for steam, charged by public companies in fifteen localities, in which the price of fuel is very variable, vary according to the consumption, based on a monthly rate, from a low point of 28.21 cents per 1,000 pounds for 10,000,000 pounds, to a high point of 90 cents per 1,000 pounds for a consumption of 25,000 pounds.

That steam can be purchased from such systems at rates which compare favorably with the cost of production in small private plants is evidenced by the large and growing number of consumers. Purchased steam requires no auxiliary apparatus such as feed, drip and return pumps, and thus stands at an advantage in this respect.

When the entire costs and accompanying losses of steam production in a building are taken into account, steam at purchased prices is frequently a source of much economy. The total cost of steam production involves more than the expense of mere labor and fuel. In private plants the value of space occupied by boilers, auxiliaries and coal is an important addition to the costs. Up-keep and repair cost from seventy-five cents to one dollar per annum per horse-power of boiler in active service.

The value of a public service of steam at certain seasons of the year, and for certain intermittent purposes, is much higher than the average cost. The operating cost of steam generated under favorable conditions of maximum demand may be as low as thirty cents per one thousand pounds of water turned into steam, but in the part of the season when the demand falls off it will be double that amount. The operation of a boiler-plant involves disproportionate expense at certain seasons of the year when there is little demand for steam. The cost of labor per ton of fuel handled is in summer double the rate in winter, and often greatly exceeds the money value of the fuel.

The cost of labor and fuel in a low-pressure heating plant in

OBSERVATIONS OF THE OPERATION OF A LOW-PRESSURE HEATING PLANT DURING THE COMMENCEMENT AND ENDING OF A HEATING SEASON IN NEW YORK CITY, OCTOBER TO DECEMBER AND MARCH TO MAY

Seven-story Business Building

Week of season	Average external temperature	Pounds of steam generated	Pounds of coal used	Evaporation from and at 212° F. per lb. of coal	Cost of coal and labor per 1,000 lbs. of steam
1	57.2	844	1,365	0.67	$16.35
2	64.6	None	None	....	10.00*
3	62.4	3,810	866	4.76	3.36
4	60.4	6,000	2,408	2.70	2.97
5	47.4	29,300	4,221	7.55	.47
6	53.0	16,500	3,687	4.89	.72.8
7	46.2	29,640	4,664	6.72	.51.4
8	38.8	42,807	5,096	9.13	.38.6
9	40.5	31,500	4,969	6.85	.51.4
10–23, or 14 weeks of mid-heating season, intervened at approximately the conditions observed in weeks 8–9, 24–25					
24	32.9	44,320	5,802	8.22	.63.0
25	41.3	31,400	5,177	6.54	.82
26	42.0	19,920	3,979	5.45	1.09
27	41.1	22,520	4,271	5.68	1.02
28	43.7	16,000	3,969	4.44	1.37
29	55.9	3,870	3,048	1.38	4.86
30	49.6	7,140	3,141	2.51	2.72
31	59.1	5,310	2,454	2.39	3.17
32	59.4	1,670	2,636	0.70	10.48

* Labor.

New York City was recently observed, during the weeks beginning and terminating the heating season, as shown on opposite page.

Municipal undertakings do not take into account features which vitally affect their ultimate results

The cost of fuel and labor during these eighteen weeks was in excess of the cost of raising an equal amount of steam by the use of gas at eighty cents per thousand cubic feet.

A public supply of steam was not available; but had it been, the cost of a supply would have been less for the whole season than the expenditures for fuel and labor alone. To this must be added in such cases incidental costs of up-keep, removal of ashes, cost of water, and the proper fixed charges on the capital invested in the boiler-plant and in the space occupied thereby.

All public distributing systems of energy were preceded, and electricity in particular was antedated nearly a century, by the distribution of water for sanitary purposes. This service was a matter of such necessity to the public that its conduct by municipalities became as general as the operation of parallel systems for the disposal of storm-water or sewage. The essential difference, however, between such systems and those of the distribution of steam or gas, of electricity, or of refrigeration lies in the fact that sanitation is a general and individual necessity, and that it involves the provision of water supply and necessitates the disposal of wastes for every class and every member of the community, for the protection of the health of all, irrespective of whether it can be paid for or not; while the other services represent either a convenience properly utilizable by those who can afford to pay for it, or a commercial and therefore profitable employment of service equally properly to be paid for by those who employ it to their own advantage. In such conveniences and profitable processes all the individual members of the public are not personally concerned.

The lack of appreciation of such essential features as these has led to essays, not always with fortunate results, in the construction, operation, and distribution by municipalities of various systems of public services, such as electricity and gas.

Municipal undertakings do not usually take into account some features which affect the ultimate results. Thus, where a municipality is able to derive an income from the leasing or granting of the use of the public highways under a franchise, it becomes in a measure a partner in the operation, to the extent not only of any return based on income or taxable property held by the enfranchised organization, but also to the extent to which its investment relieves the public of the commensurate investment of public funds. If, upon the establishment of such a partnership, the municipality undertakes to compete with its partner, it becomes a loser to that extent of its share of the business, and also by the inroad upon its resources made by the capital investment. If, in the course of such competition, a municipality should invest the money of the community in apparatus, the purpose of which is to compete with the product of the enfranchised system, the process thus becomes doubly expensive. From an economical standpoint, the capital expended has offset the value of an equal outlay in the public system. The municipality's capital is then rendering unproductive a similar amount of private capital, the use of which in serving the city brings a return to the city by taxation. Whatever may be the revenue in taxes from a similar capital invested by the supplying company is lost to the city, and must be considered as a reduction of the value of the operation of a municipal system.

The investment of private or public capital in operations of this character has other and far-reaching effects. Unless the net returns, after reduction by present costs and future contingencies, be as ample as the returns which could be obtained by the expenditure of the same capital in other necessary or useful public directions, then such an investment of taxpayers' property has neither economic nor commercial value. It becomes a mere log, a dissipation of so much human energy as was consumed in its construction and is utilized in its operation.

The investment of capital in machinery is a gamble against future reductions in the commercial value of the product

The investment of private funds in appliances for the production of energy is a commitment of available moneys or credit in apparatus of limited endurance, and is, further, a gamble of the present results against a probable reduction in the commercial value of the product, and of the cost of energy commercially produced on a larger scale.

CHAPTER VI

THE USE AND WASTE OF ENERGY

The cost of a gratuitous convenience is concealed from the user, while the extent of its usage is at his discretion

THE USE AND WASTE OF ENERGY

A STUDY of the utilization of energy for commercial purposes, or for domestic convenience, should be extended beyond any given locality in order to obtain a view of its value and effect. Thus, in order to appreciate the character of such services as heating and lighting, or the use of refrigeration, the climatic effects and results of seasonal variations should be considered. The necessity for, as well as the cost involved in, the heating of buildings is decided by climatic conditions, the process being totally negligible at the equator and reaching a maximum value in the polar regions.

The need of refrigeration might be considered as inverse to heating, but is affected less by climatic conditions than by the commercial requirements of foods in centres of population. It may be, for instance, as much a necessity in this regard in a community in Canada as in one in the West Indies, notwithstanding the difference in exterior temperature at certain seasons.

The need for artificial lighting of buildings varies by latitude, and also by the season. The extent of interior lighting required in any building is primarily determined by its design, and the usage is developed by the occupation, and is specially affected by local conditions. Comparatively few buildings in crowded cities are so situated or planned as to afford access of natural light to all parts of the interior, deficiencies now readily met by the facilities for the distribution of artificial light by means of gas or electricity. Such conditions lead to the consumption of a large amount of energy in interior illumination in the daytime as well as during the hours of darkness. The commercial value of natural light in buildings has not yet become fully appreciated by their designers. Rental values are reduced by deficient light. The lower parts of some very expensive business buildings are rented at greatly reduced rates, a loss not counterbalanced by increased rentals for upper portions.

In the use of any or all of the conveniences provided in modern buildings, the habits of occupants have been increasingly in the direction of wastage. The effects of such habits are very pronounced in the City of New York, in which a system, unfortunate in its effect upon the owners of improved property and their tenants alike, has become established in many business buildings, and in some classes of residential premises, by which such conveniences as heating and lighting, and in some cases even refrigeration, have been included in the rent and are not charged for directly. The use of the convenience which is assumed in the charge made for it is, of course, that it shall be of reasonable extent, but the cost of the service afforded is thus concealed from the user, while the extent of the usage is placed entirely in his discretion. It being thus no direct object to economize, but, on the other hand, requiring some little exercise of care to do so, negligence becomes the easier process, and unnecessary extravagance in the use of such conveniences has become general.

The process, strange to say, has been further advanced by the very class who would naturally be expected to be in favor of its diminution. Owners of buildings in which such practices have built up a larger use than is economically necessary, maintain household heat and power producing plants of machinery, and often base their necessity upon the maintenance of these wasteful conditions. The effect of extravagance in the use of

The operation of power apparatus involves the use of some part of its own product

the product of the apparatus is to create a large volume of the product, which, if divided into the costs of operation, presents a relatively small unit cost. The difficulty of dissecting such costs is greatly enhanced where a number of interrelated services are provided. The greater the waste of electricity, for instance, the larger is the output of the power-plant, and the less the cost per kilowatt-hour. By doubling the use of energy from a plant with the same amount of labor, the cost of labor is spread over twice its previous product.

A large amount of a certain product, such as heated water, may appear relatively cheap per gallon, although a considerable proportion of the total may be attributable merely to wastage. The apparent cost of raising steam may be made to appear less per one thousand pounds than its purchasable price, because a greater volume than is necessary is being raised by a given amount of labor. Even deliberate wastage sometimes proceeds with the idea that the volume of the output becomes thereby relatively cheaper. In other words, the greater the output which the employed labor can turn out, whether useful or not, the less is the relative cost of their services. A contributory element in this connection is the fact that the operation of any power apparatus involves the use, for its own operation, of a part of its own product. The engine-room requires energy to light it, and also to ventilate it; the fire-room may require not only ventilation and lighting, but also the use of some part of the steam generated, to assist or accelerate the combustion of fuel in the furnace, or to clean the tubes, or to operate its own feeding appliances. Such usages are practical additions to the cost of the net or usefully utilized part of the product, just as the man riding on the wagon becomes a burden on the service of the team. Yet it is not uncommon to see figures of cost which include the part of the total product thus ineffectively dissipated, included in the total for the ascertainment of a unit price. The process is analogous to the ancient system of endeavoring to hoist oneself up by one's boot-straps.

Thus, one large store operates a private power-plant which generates four million kilowatt-hours per annum. Another, somewhat larger, and doing exactly the same kind of business, consumes less than one-half the amount from a public supply, and includes the operation of electric elevators in the energy used.

As a homely illustration of these points, take such a simple situation as a domestic household's use of soap. The customary requirement for this material may be well established, and its purchasable price known. If the householder now proceeds to install machinery for the purpose of the manufacture of soap, the moneys so invested are taken away from the credit or use of the family and embarked in appliances, the life of which is limited to a certain period of years. The output of the apparatus involves a certain amount of labor diverted from household duties, or introduced as additional labor. The result of the application of capital, labor and materials, plus maintenance and repair, is a capacity for the production of an amount of soap probably far in excess of the normal household usage. The methods of the household will not unnaturally change under such ready facilities for obtaining the material, and much more is consumed by reason of negligent habits and methods. The total output, however, though in excess of the real requirements of the family, when divided into the cost of production makes the product cheaper *per pound* than the price at the grocery. These methods and habits are diametrically opposed to the wholesome principles of thrift.

Sometimes an apparent economy becomes a source of waste. The use of cheap grades of fuel requires a high degree of draft for its combustion, and steam jets or fans are operated for this purpose.

Sometimes an apparent economy becomes a source of waste

A steam-jet under a furnace will dissipate from two per cent. to nine per cent. of all the steam generated, which amount forms no useful part of the actual service provided, and reduces the value of any saving in fuel effected by the draft. The use of a blowing-fan or the lighting or ventilating of an engine-room is of precisely the same character, and so is the power required to operate auxiliary machinery, the purpose of which is merely attendant upon the operation of others. Thus a feed-pump or a drip or return pump performs no utilizable service, and is an appendant upon the net output of a power-plant.

The same principle applies to the feeding of employes, or, as is done in hotels, the housing of others. The cost of meals, which in New York averages fifty cents per employe per diem, is an unproductive addition to the cost of the net output of the plant they attend. In certain hotels, not only do the engine-room employes obtain their meals free, but they use a gas-range to heat the food. The cost for the food supplies to the staff in charge of machinery in a large hotel of the first class adds to the cost of operation of the plant about fifteen thousand dollars a year. In a smaller hotel of high class the cost is about four thousand dollars a year, adding about seventeen per cent. to the cost of labor. In a small apartment hotel it is nearly nine per cent. of the operating costs of the whole plant. The cost of all mechanical services in a modern hotel is about fifty cents per guest per diem, if the hotel be fully occupied. If the patronage falls off, the relative cost increases. In summer time the cost, in city hotels, may be as high as fifty per cent. of the room rentals.

Wastages in the output of generated energy by pumps, engines and dynamos are frequently excused on the assumption that a part of the steam used in the generation of electricity or the operation of pumps may be usefully utilized for another purpose, namely, that of steam-heating. This idea is pursued in some cases so far as to excuse wastages of energy because steam employed in its production may then effect to a greater extent the secondary purpose of heating. According to the point of view or to the interest of the person engaged in its observation, either the wastage of steam or the wastage of electricity is regarded as a "by-product," and is therefore justifiable. Such assumptions ignore fundamental facts underlying the development of energy, and the relation thereto of the appurtenant burdens of labor and of maintenance.

The production of a manufactured product, in power as in materials, is the result of the combination of three elements: invested capital, purchased materials, and human energy. Each requires a commensurate return, and unless that be provided the combination is incomplete and the result ineffective. Thus, when the employment of labor is for the purpose of operating a combination of services, the wastage of one for the economy of another has no bearing, except upon the total result. The labor and materials are both unproductive, unless the gross effect of their combination is to produce a return upon the capital embarked in the undertaking.

The man who operates a business at a continuing loss is losing also all the value of his own energy and wasting fruitlessly all of that of his employes. Only to the extent, therefore, to which a by-product will increase the total utilized output of the labor employed is it of value. To waste one product to any extent beyond its own necessities is bad, and if the secondary usage is also wasted, then the error is magnified.

If the demand for and value of the secondary product be fixed, determinable and regular, then the process of conducting a primary process so as to provide the secondary would be practical and valuable. But the heating of buildings is not so. It has no relation to other services, it varies by unknown and undeterminable atmospheric fluctuations, it exists only a part of the year, and less in one place than another. Every conceivable element of variability attends its use. As a subject for the use of a by-product of energy, it is as far removed from an ideal as possible.

The value of exhausted steam may be offset entirely by accompanying losses in production

The primary product also varies, but not by the same laws nor to the same extent as does the work of heating. Its production is accompanied by a fixed proportion of losses in the form of auxiliary appliances, and even by the use of part of its own product.

Under the climatic conditions of New York City, the utilization of exhausted steam in the heating apparatus of buildings occupied by power-plants is proved to be no more than one-third of the total steam raised during the year, and this only where the conditions are favorable to such a combination. Supposing, then, that the by-product of waste steam represented one-third of the total heat used and discharged by the plant: if the operation of the plant should involve, as it may do, the absorption of twenty-three per cent. of the energy it produces for contributory purposes such as lighting and ventilating machinery spaces, running service elevators, etc., and should also involve the consumption of ten per cent. of the total steam supply for auxiliary services such as pumps, then the value of the by-product of exhausted steam has been offset entirely by the losses accompanying the total production. These proportions happen to be those which were ascertained in an actual instance.

Further, if the conditions of generating power were more favorable to the utilization of exhausted steam, it would still be a matter for inquiry whether the exhaust represented to any degree an unrequired or unnecessary product. If the exhaust was derived from a house-pump, the work of which was in part wasted by the reckless use or leakage of the water it pumped, then its exhausted steam to that extent represents no value.

Such wastages are very prevalent in all services of modern buildings. They are established by a variety of causes. Thus, in the operation of elevators recklessness in use and negligence in attendance tend to increase very markedly the amount of energy required for operation.

In hydraulic elevators of the plunger type, the valve-motions may absorb from eleven to twenty-two per cent. of the total energy used, according to the demands for stoppages and reversals of the machine. In the operation of electrical elevators, the largest proportion of the energy used is occupied in the processes of starting and of stopping the car, and in its acceleration and retardation. The number of stops and restartings made in each mile of car travel is the major element in determining the amount of energy used. Every unnecessary reversal of motion constitutes an additional demand upon the energy supply. Unnecessary stops and starts are common results of the careless habits of passengers, as well as of the incompetency of operators, or are due sometimes to the lack of proper signalling systems. They are often due also, in part, to an unduly high speed of the apparatus, which has been provided with the mistaken idea of increasing the capacity for service, but which usually results in an actual decrease in efficiency.

The wastages in household sanitary conveniences, such as hot and cold water, are so frequently evident as to need little description. The efficiency of sanitary hot-water systems is very low on account of the losses due to radiation of the heated water sluggishly circulating in the pipes. Of the total heat imparted, about thirty-three per cent. is thus lost under the conditions of office-building service. In summer the loss is relatively greater, due to the less amount of hot water used. Both hot and cold water systems are subject to much wastage by careless use, and also by the defective method of design and character of materials employed in their construction.

Mention may particularly be made of the wastage of iced

Services gratuitously afforded to tenants invariably engender wasteful habits

drinking water, a super-convenience which has been added to certain business buildings, public and private, the excuse for which has either been the desire to present some superior form of attractive convenience to tenants, or to eliminate the handling of bottled drinking water and ice in the building. It may be observed that, under proper management, little if any inconvenience need be experienced from the introduction of these supplies, but as soon as a refrigerated service of iced water is installed the same wasteful habits engendered by service gratuitously afforded appear in full force. It is only necessary to watch the average user drawing water from such a source to note that for the amount actually consumed, fully three times as much is usually thrown to waste. This is a wastage not only of the product, but of its accompanying losses and costs.

The cost of circulating supplies of drinking water is largely in excess of the actual cost of refrigerating the water drawn from the system, let alone the amount actually consumed. A careful test upon a well-installed and well-utilized plant in a manufacturing and business building in Manhattan showed that of the total refrigerating effect provided, eighty per cent. was lost in moving the water around in the piping, and only twenty per cent. was utilized in water actually drawn from the system. Probably one-half to one-third of this is all that is actually consumed.

As a comparative illustration of the exaggerated results under municipal operation, it was found in a city business building that only five per cent. of the refrigeration effect was represented in the water drawn from the system, and ninety-five per cent. was lost in moving the water around in the piping.

The lack of foresight exhibited by public authorities in the past in the construction of the sewerage system of certain cities, notably in New York, has resulted in the sewers, which are designed to drain away the sanitary wastages of the buildings, being in many cases situated above the level of basement floors. This is particularly the case in most of the modern buildings of all classes in the Borough of Manhattan, the drainage system of which lies at an average of only thirteen feet below the crown of the roadway, while basements and sub-basements are below that level.

It thus comes about that nearly all buildings of any large size are involved in the cost of the installation and operation of sewage-pumping machinery, which is required to be maintained in operation at all times in order to meet any possible contingency arising from interior or exterior flooding of the lower part of the building.

The conditions are aggravated by the construction of sub-basements extending to considerable depths below the street, the construction of which is mainly due to the provision of space for machinery. Sub-basements in New York usually extend to a depth of twenty-four feet, though several have been constructed with an additional sub-floor for machinery often extended down in solid rock. This is relatively the most expensive operation in building, both for first cost and also for permanent maintenance, and at the same time it has the least commercial value.

Such spaces are rendered more costly by the installation of sanitary appliances in them for the convenience of occupants such as engine and fire room attendants. Their use involves not only the provision and operation of sewage-pumping machinery, but additional costs of operation by continuous artificial lighting and artificial ventilation. The net value of sub-basement spaces, after deducting light and sewage pumping, is much less than their apparent value. Some spaces earn less than interest on their cost. The burdens involved by such conditions are often ignored in considering the cost of the operation of power-plants so situated.

Much the same conditions surround the supply of water from

Knowledge that a service is purchased tends to induce greater care in its utilization

municipal sources, the arrangements in connection with which are so inadequate in the City of New York that few buildings above a height of six stories are able to secure a supply on upper floors from the city mains, and the majority are compelled to resort to mechanical appliances in order to raise water to higher floors.

The investment of property-owners in machinery of this character, and in the enormous and unsightly roof-tanks which disfigure the appearance of the city, would have paid a large share of the provision of water service of more effective character, and the cost of private repumping is probably greater than the cost of applying a pressure to the whole system. The cost of water in New York is one dollar per one thousand cubic feet. House water pumping adds about forty per cent. to the purchasable price of the water. This cost is often unnecessarily increased by defective piping arrangements. Lower parts of buildings which could be supplied without pumping, often are so connected as to derive their water from the pumped supply.

The re-use or secondary utilization of water may be a source of economy, but is rarely adopted. Water that has been passed over the cooling coils of condensers is not contaminated, though it is warmed, and it may be utilized for house services. In a Broadway office-building a supply from a driven well was adapted to several secondary purposes. It was pumped through the refrigerating condenser to a receiving tank at an upper floor. Thence it fell through an air-compressing device which was used to supply air to lift sewage. Thence it fell to another receiving tank on the lower floor, whence it was drawn as required by sanitary appliances on the floors below. The process saved nearly eleven hundred dollars a year in the cost of city water.

It has been observed that the amount of any service provided by a private plant, such as steam, water or electricity, which has been by some method or other developed to a wasteful extent, is always reduced upon the introduction of a purchased service. Knowledge of the purchase of the service always tends to induce some greater degree of care in its utilization. An instance of this character in an electrical service was succeeded by a return to the operation of a generating plant. The consumption of electricity at once began to increase, and after a couple of seasons was nearly at the same rate as had prevailed before the plant was abandoned.

There are, of course, many ways in which such careless usages may be rectified. The most effective is, naturally, to cause the user to pay directly for what he uses. But where this cannot be done, changes of method can be made effective. In business buildings heat and light are wasted by the cleaners working in night hours. Regulations directing the shutting off of radiators and restricting the number of lights in use by cleaners have produced substantial reductions. The abolition of unnecessary corridor lighting, or a reduction in the size of lamps and radiators in such spaces, is another source of economy. If a meter be occasionally applied to the service of individual occupants, a check on wastage can be secured. Such observations have disclosed extraordinary burdens imposed by wastefulness, greatly reducing the value of the rental obtained.

The relation of operating costs to rentals is a study which should be made by every proprietor of leased or rented premises.

Of the total rentals the operation and taxation of an office-building in New York are about	50	per	cent.
The largest single item is taxation, which averages	15	"	"
Management, up-keep and cleaning cost	15	"	"
Elevators, lighting and heating	18	"	"
Or with vacuum cleaning and refrigeration added	20	"	"

Rentals paid by careful and economical tenants cover the wastage of negligent neighbors

In elevator apartment houses the cost of these conveniences is from twenty-two and one-half to thirty-one per cent. of the gross rentals. When rentals fall off or vacancies occur, the proportion becomes much higher. Such conveniences often cost more than the net return upon the property.

Were it not for the conveniences which tenants now expect with their rent, some of which our forms of building have involved, rentals of business buildings could be reduced twenty per cent., lofts fifteen per cent., apartments thirty per cent., and flats ten per cent.

The rental charged must more than cover the usage made of these conveniences of heat and power, otherwise the ownership is conducted at reduced profit or at a loss.

The cost of maintaining conveniences such as heat, elevators, and (in part) lighting is not materially reduced by vacancies in a building, unless they be extensive. But combined with vacancies it may, and often does, wipe out the profit of ownership.

Loft property has been increasingly attractive because in such buildings tenants usually provide for their own light and power by direct purchase from a public supply, and often clean and heat their own premises.

Few persons realize how much they are paying under cover of rental for what they conceive to be a full value. The rent paid by the careful and economical tenant covers the wastage of a negligent neighbor. The rent of the down-stairs tenant supports the elevators and water supply of up-stairs neighbors. The system is utterly lacking in inducements for thrift or care.

It is largely the community class of building which brought into being the supply of free services, and these resultant effects. The concealment of taxes in rent has had far-reaching effects upon public affairs. It is recognized now that the tenant cannot be roused to an interest in public affairs, as he should be, because he persists in regarding himself as a non-taxpayer. But the average business man in New York City pays from ten to seventeen per cent. of his home rent in taxes, and from twelve to twenty per cent. of the rent of his place of business is devoted to the same purpose, making from eleven to eighteen per cent. of his rent payments paid indirectly to the city. If the rent of his home is one-fourth of his income, and that of his place of business another one-fourth, then he is paying in taxes about seven per cent. of all he earns.

About similar proportions apply to the conveniences provided in buildings, the cost of which is paid in rentals, so that for taxes and conveniences the business man may be said to be working one-seventh of his time. Since both processes seem to be on an increasing scale, the burden is not growing lighter as time proceeds.

It is interesting to observe how the habit of usage, if not of wastage, increases as the price (but not the total cost) of a convenience decreases. A number of old gas bills were found among the papers of an old-time New York business house. When gas cost seven dollars per thousand cubic feet, the store had a single burner. As the price fell more lights were added, and the total amount which was paid increased over a long space of years, and when the price was reduced to one dollar the total amount paid for lighting was greater than in the early days of the supply.

CHAPTER VII

COMBINATIONS OF MACHINERY AND LABOR

Conditions are markedly in the direction of simplicity when services are secured from public systems

COMBINATIONS OF MACHINERY AND LABOR

COMBINATIONS of mechanical appliances are necessary to meet the needs of the occupants of modern buildings, and the tendency of modern invention is generally towards an addition to the number. Conditions are markedly in the direction of greater simplicity when necessary services are secured from public systems of distribution.

The manufacture of high-pressure steam upon private premises involves the use of sundry minor appliances, even when laid out upon the simplest method, but their complexity greatly increases if steam be also utilized for power-generating purposes. The operation of low-pressure steam-heating apparatus may be made extremely simple, but it becomes more complicated if it be adapted for the use of exhausted steam, even at the same pressure. The operation of heating buildings by circulating hot water is as simple as that of steam-heating, and has much to recommend it for domestic purposes in its more moderate temperature of the heating surfaces, its less rapid variation of temperature, and its less amount of attendance or labor.

Steam-heating has, however, an advantage in being quicker in responding to sudden demands, and under the prevailing conditions of modern business and commercial buildings is generally preferred. It is also somewhat cheaper to install. The operation of steam-heating apparatus has its own difficulties, chief among which is the elimination of air with which the steam is always more or less charged. This can be brought about by the simple process of using a pressure somewhat above that necessary for the circulation of the steam, forcing the contained air out through one of many forms of air-valves; but if the system is desired to be operated by exhausted steam, either wholly or in part (and usually the latter), the pressure necessary to expel the air becomes a detriment to the economy of steam-operating engines and pumps, and involves the use of apparatus for eliminating the air by suction, with special appliances, sometimes operated also by steam, which thus become a charge upon the combination.

Even if these auxiliary appliances, when operated by steam, be connected with the heating system so that the exhausted steam does part of the work of heating, the amount so utilized displaces a similar amount of that utilizable from the engines or pumps to which they are appurtenant. Equipment of this nature may include vapor-pumps operating what is known as a "vacuum," drawing both water of condensation and the air contained in the steam from each radiator; or may consist of a system of suction upon the air-valves of the radiators, produced by ejectors using jets of high-pressure steam. Appliances such as these may consume as much as from three to fifteen per cent. of steam additional to that used in the heating system.

The number of the minor appliances which are now customary accompaniments of the operation of steam-power-generating plants in private buildings has become quite large, and as the services of most motive apparatus must be safeguarded against their liability to failure, they are usually provided in duplicate. The combination of various services in modern buildings therefore involves quite a complexity of small appliances, over and above the main element of steam-generating or of power-generating machinery. The number is increased where the building is equipped with several forms of power transmission, such as electricity, compressed air, or, *Auxiliary power-plant appliances fasten heavy burdens upon the cost of steam heating*

in the case of elevators, hydraulic power. In the latter case pumps are used for the purpose of affording necessary pressure, and these are usually in duplicate, and sometimes in triplicate. To their number is generally added a high-pressure pump utilized in raising a specially high pressure in order to operate an elevator when carrying an excessive load, such as a safe. In addition, hydraulic systems require air-pumps to maintain the elasticity of the supply of water to the elevator cylinders, the air being pumped into the closed hydraulic tanks and replenished from time to time.

The degree of complexity and the number of appliances involved have a direct effect upon the amount of labor employed. Thus the greater the effort to procure a high degree of efficiency in the reduction of the consumption of fuel, the greater will be the amount of labor involved in the operation of refined appliances required to produce efficient results. A similar course attends the minor expenses of supplies, of materials, and of up-keep and repair.

There is no fixed financial relation, but there is an economic connection, between the cost of engine and fire room labor and that of fuel in privately-owned power-plants. If a plant is of poor economy, the cost of fuel may be greater than that of labor. Where a plant is of moderately economical character, the cost of fuel and that of labor will approach each other. Where a high economy and therefore complexity is a condition of operation, the fuel bill will be less than the labor bill.

The cost of fire-room labor only in a number of commercial buildings in the Borough of Manhattan, all utilizing anthracite fuel in modern boilers, varies from the lowest point, in the largest and best-managed instance, where the cost is less than twenty-five cents per ton, to the highest observed cost in a business building, where the labor cost rises to eighty-six cents per ton of fuel consumed.

As soon as governmental operations of a similar character are examined, a marked increase in cost is observable. In one of the best managed of that class of buildings in which bituminous coal is used, the cost of labor per ton of fuel was one dollar and thirty-one cents, which added forty per cent. to the cost of the fuel.

In this fire-room seven firemen and four coal-passers were employed, the wages of whom were $7,200 a year, and who handled 5,482 tons of coal per annum.

These conditions may be compared with those prevailing in a commercial office-building, in which a somewhat larger amount of fuel is annually consumed. In this building three firemen, aided occasionally by one of the oilers on duty, handle 5,840 tons per annum, their wages being $3,285, or a cost of fifty-six cents per ton of fuel. The hours of labor are the same as in the government building.

As soon as the operation of municipal buildings is examined, a marked increase in cost, not only over the commercial, but even over Federal conditions, is apparent. In a city building under carefully supervised conditions the cost of fire-room labor per ton of fuel consumed is one dollar and sixty-six cents, representing more than fifty per cent. added to the value of the fuel, and being one hundred per cent. more than the highest commercial cost. The quantity of fuel handled was slightly less than that in the commercial office-building, but it involved the employment of seven firemen and a coal-passer, at a cost for wages of $8,577, as compared with a cost of only $3,285 under the same conditions of fuel and the same hours of labor in the commercial operation.

Other instances in the City of New York may be cited to show that the foregoing was by no means an unusual condition.

The cost of fire-room labor in a prison building is one dollar and seventy-four cents per ton, notwithstanding the fact that the labor of wheeling and much of the handling of the fuel and ashes is done by short-term prisoners. In another departmental building the cost is three dollars and fifty-nine cents per ton, which practically doubled the cost of the fuel.

Wage-earners provide the largest share of the cost of excessive labor in municipal employment

Organized labor has not so far recognized a responsibility for the maintenance of such conditions in city employment, nor have wage-earners yet realized that it is they themselves who are to the largest extent the source of the funds necessary to maintain excessive labor in municipal employment. The taxes from which their support is derived all come eventually from labor by indirect contributions in rents and in the value of materials created by the work of man.

Suitable arrangements for the avoidance of muscular labor in the transfer of fuel and ashes may substantially reduce the cost.

The operation of firing boilers in one of the largest and best-managed office-buildings, where as much as thirty tons is consumed in a day, is conducted by only three firemen, each working upon a watch of eight hours, assisted by two coal-passers, each working upon a watch of twelve hours. The fuel is delivered by gravity to a car which is wheeled to the fire-room in front of the boilers, so that the firemen's labor is reduced to the transfer of the fuel from the car to the furnace, involving no lifting of the coal. Not only is unnecessary muscular effort reduced but the intelligence of the fireman is better utilized. The cost of this labor per ton of fuel at times of large output is as low as twenty-four cents per ton of two thousand pounds, which is much less than the same operations in buildings where the fireman is required to lift the coal from the floor to the barrow, and again from the floor to the furnace. The mechanical work under these favorable conditions represents a maximum capacity of the labor employed of nine tons weight per man per diem.

The character of fuel may add largely to the labor involved in feeding and in cleaning fires by an excessive proportion of ash, clinker and cinder. In low grades of anthracite the incombustible material is always in excess of fifteen per cent. by weight, and in some cases exceeds twenty-five per cent. The character of the lower grades of anthracite has been steadily deteriorating in this direction, due to the demands upon the supply. These grades were known as "Buckwheat" Nos. 1, 2 and 3, and below the third, as "Rice." At the present time No. 2 Buckwheat is of less value as a heating agent than No. 3 was a few years ago. These grades consist of the fine granulations due to screening, and the lowest are the result of a washing of the culm, which in years gone by accumulated in immense piles at the mines. The heat content in these grades is variable.

In a central station using a similar class of fuel, which is, however, handled in bulk, and is delivered to the fire-room by automatic appliances, though fired by hand, the cost of labor per ton of fuel is reduced to fourteen and one-half cents per ton, though the firemen are paid about forty per cent. more wages than the prevailing commercial rates. Each man thus employed during an eight-hour shift handles about twenty-one tons. The effect of the use of completely automatic supplying and firing machinery is greatly to increase this capacity. The capabilities of the man are thus enhanced, and while relieving him of muscular effort, his intelligence is utilized in directing larger operations, which are represented by an increase in the wages earned.

The rate of fuel combustion under a given boiler may be such as to render hand-firing impracticable. Boilers are in operation in central-station service which at times of large demand consume bituminous coal at the rate of seventy-five pounds per square foot of grate area per hour. Hand operations would be quite impracticable under such conditions, and are replaced by the same motions automatically produced by machinery,—controlled, however, by the more highly-paid services of a lessened number of operators for a given amount of product.

In domestic heating, fuel and labor are utilized to such poor advantage that gas may be cheaper

In large power-plants where such economical appliances are installed the cost of engine-room and boiler-room labor combined is less than that of fuel. A plant of a capacity exceeding 20,000 kilowatts, favorably situated as regards coal supply, will afford energy for about half a cent per kilowatt-hour, made up of the following elements:

Fuel at $2 per ton	0.170 cent.
Labor	0.126 “
Interest and depreciation	0.172 “
Supplies	0.026 “
Repairs	0.022 “
Total	0.516 cent.
For any other price of fuel add per $1 additional cost	0.085 “ per kilowatt-hour.

Other forms of fuel, though relatively more expensive, may under some conditions become economically advantageous.

A public supply of illuminating gas may be utilized with economy for many purposes now served by the use of coal and steam. Gas has a heating value of about 750,000 units per thousand cubic feet. Compared with coal at a price of say three dollars per ton, containing the same amount of heat in about sixty pounds weight of the fuel, it would appear that the cost of gas for heating operations or in raising steam for other purposes would be hopelessly at a disadvantage. But in domestic heating operations the fuel usually is of a more expensive character, and is utilized to such poor advantage that the operation of heating by gas may be cheaper under many circumstances.

The operation, for instance, may be practically automatic, so that the use of gas eliminates the cost of labor required to handle the fuel and dispose of the ashes. The amount of gas used is reduced by its greater adaptability to variations in demand. The heat in coal is in such operations utilized only by about fifty per cent. There are seasons of small demand when such fuel as gas would be far cheaper than coal and labor.

Under the conditions in which steam is commonly used in city buildings, the labor employed in handling the fuel required in winter is often most uneconomically proportioned to the fuel required in summer. Where the relation of labor to the cost of fuel handled is, in winter, in the proportion of one to two, these proportions become reversed when the fuel drops to one-fourth winter requirements during the summer months.

There are numerous cases where the only real requirement for steam during the summer season is in the heating of warm water, or in the supply of some small amount of steam for cooking or laundry purposes. The elimination of fuel and labor and accompanying expenses during the summer season will justify the use of gas as a substitute, even apart from the fact that gas utilized for such purposes can be more efficiently operated, and for cooking purposes, in particular, is more desirable, than coal or steam. The best economy of large steam-boilers will not utilize, under a favorable condition of operation, seventy per cent. of the heat value in the coal. But this utilization rapidly falls off if the output of the boiler is decreased much below its rated capacity, as is usually the case under summer conditions of operation.

Considerations such as these may indicate means by which the cost of operation of some private steam or power generating combinations may be reduced. By some rearrangement of methods, including perhaps the partial replacement of appliances by more modern apparatus, the cost of labor at certain times of the year may be reduced, or by the substitution of other means, such as gas, capable of producing more effective service with a lessened amount of total expense, existing conditions can be substantially improved.

Long use of apparatus leads to habits and prejudices which are adverse to economical changes

Combinations of household machinery with kitchen and laundry appliances are common, in which the use of steam for all purposes has been adopted as an apparent means of over-all economy. But in the light of the reduced costs of supplies of gas and of electric energy, with increased domestic expense for labor and up-keep, the over-all economy has become a source of loss.

The changed conditions in some hotels in particular are not appreciated, because of the fixed habits which have grown up by the long-continued use of a given class of apparatus. Thus it is difficult to convince some chefs that better and easier work can be done in the kitchen by gas, and that baking, boiling, roasting and broiling processes are all capable of superior control and more effective results in less time by its use.

The use of certain kitchen apparatus of a minor character, in which high-pressure steam is used, necessitates the maintenance of a service under high pressure, with accompanying expense of labor, when the same results could be secured by low-pressure steam in a modified form, or by gas in a new form of the appliance.

A large hotel of the older type is usually provided with hydraulic elevators, steam-driven appliances of various kinds, such as refrigerating machinery and pumps, and kitchen and laundry apparatus requiring the use of high-pressure steam.

This combination is now confronted with changed conditions brought about by newer methods and increasing interior costs.

The elevators can be altered at not excessive expense to an electrical form, the supply of electric energy for light and power can be purchased at advantageous prices, the operation of water-pumps and of compressing engines for refrigeration purposes can be effected by substituting electric motors for steam-cylinders. All these would bring about the reduction of labor, and the cessation of the use of fuel, except for necessary house-heating in the winter season, were it not for the character of service demanded in the minor operations of the laundry and the kitchen.

The whole of the large economies thus producible become chargeable against the operation of these minor services, rendering them of very costly character.

Carefully considered, some processes apparently economic become excessively costly. The operation of a hotel laundry may be an apparent source of saving of expense as compared with the price of the washing on a wholesale contract. But if the laundry involves the continuance of a generally expensive condition in other directions, it may be the source of a serious continued loss.

It is safe to say that very few domestic steam and power combinations at present in operation could not be modified so as to produce equivalent results at less cost, by the use in whole or in part of purchased services of steam, gas or energy at prevailing prices. Where such installations have been in operation for a long period of time, a recombination involving the replacement of old machinery becomes an advantage extending far beyond the question of efficiency and cost of operation of any one element in a plant.

In the investigation of the plant of an insurance building it was found that substantial advantage to the services and an increase in the rentals of the building could be secured by a reconstruction of the elevators from an old-fashioned pattern to a modern effective design. The result of such a change, combined with the use of tungsten electric lamps and a reduction in the pressure of steam for house-heating, would thus have been to reduce to some extent the costs of the plant operation. But a far more important feature was that it would also bring in an increased income from the building. This effect far outweighed the extent of cost or economy in the domestic plant.

The absence of machine attendants upon work outside the machinery spaces is not justifiable as an economy

It is sometimes difficult for the owners of buildings, particularly the proprietors of hotels, to give full consideration to such changes in a plant as will produce a reduction of cost, if they be accompanied by a reduction in the labor employed. This attitude is often due to the fact that the management of some such establishments have acquired the habit of employing their engineers upon all sorts of useful errands and minor duties, and have become accustomed to depend upon them in these directions. They cannot realize the effect which such a practice has upon the maintenance and operating cost of their plant. The absence of the attendants in charge of operating machinery upon other errands is not a source of economy, but of loss, and the employment of engineers, at prevailing wages, upon jobbing work and house repairs around buildings outside of the machinery spaces is not justifiable as an economy, especially when the control of the consumption of fuel, and the management of machines using steam, are being left to the less skilled and less capable class of labor.

An instance of this nature was found in the case of an institution in which the chief engineer, who was paid an unusually liberal salary, spent nearly all his time away from the machinery spaces upon various useful assistance of officials in other parts of the building. As a result, the condition of the expensive power-plant became very much neglected, involving large costs for replacement. The main steam-piping was in a very bad and leaky condition, and the minor appliances were all out of order. An ammonia-pump in a refrigerating plant was operated by a piece of string tied to its valve-gear. It need scarcely be added that the handling of fuel in the fire-room was deplorably ineffective. The cost of operation and repair of this plant was largely attributable to the absence of the operating engineer.

In this instance, however, and in a number of others, an operating engineer in domestic employment often attains a position of influence in the establishment which secures to him the confidence of his employers, due to his intelligence and ability, and his willingness to make himself useful, and this sometimes prevents the proprietors of such establishments from considering any rearrangement of their organization which might appear to be likely to deprive them of the valued services of this capable assistant. But it should be recognized that the services thus rendered are not directly connected with the operation of the power-plant, but are extraneous thereto, and warrant expense on their own account. Services thus diverted from their real purpose should be charged to the service rendered. If not, their burden is being transferred to the operation of machinery.

Labor actually required in the control and management of power machinery, if diverted from that duty, involves expense in depreciation of its condition or expense for repair of neglect. But, on the other hand, the services of many engineers may be usefully utilized to some extent in other directions than the care of machinery, if that machinery can be dispensed with by some other system or method.

If the engineer of a plant is employed practically all of his time on extraneous duties, such as building management or office duties, then the plant is being operated by a less experienced class of labor, and may be suffering therefrom, while the duties that are being performed by the engineer are other than those for which his training has specially qualified him, and he may be receiving, as is the case in certain instances, a greater amount of remuneration than should be paid for the business service or repair work which he is affording.

The process of a recombination of mechanical services, or of the reduction of operating machinery, need not, and does not, involve dispensing with the services of the engineer in charge of such operations, but involves only a change in the character of service rendered. That service may call for a greater exercise of individual energy on his part than is frequently found to be the case under existing conditions, where such an official has been accustomed to the employment of a considerable number of subordinates and his actual work is limited to their control or direction. It may call for a readjustment on his part of his duty as regards his employer's financial interests, and a readaptation of his own capabilities to the changed conditions. The chief engineer who has been accustomed to handling steam-generating machinery may have to constitute himself—which he can readily do—an economist in the usage rather than the production of electricity or gas or steam. In so doing he is equally serving the interests of his employer, and may recognize in these conditions an opportunity of rendering better service even for an increasing extent of remuneration.

Economy in utilization is of little consequence to operatives of domestic power-plants

Under such circumstances the services which he is capable of rendering may be of larger value than those heretofore afforded in the control of the operation of steam or power generating machinery. Instead of being a mere attendant of the output of a few machines, he may and will become a director of economies, specially qualified by his prior training to deal with this more important subject, and charging himself with the duty of prevention of much of the prevailing wastes of heat and energy.

Under existing conditions it is of little direct consequence to the operatives in power-plants that such wastages are in existence; but when the services are being purchased it becomes their direct interest as well as duty to devote attention to the attainment of true economy in their use.

There are larger opportunities for usefulness and for increase in the value of service in this direction than in the continuance of existing conditions of mechanical attendance upon machinery.

The value of labor is greater in the reduction of wastage and the promotion of economic use than it can be in attendance upon production under domestic conditions.

CHAPTER VIII

THE PROPORTIONS OF MACHINERY AND LABOR

Economic performance varies with each class of power apparatus

THE PROPORTIONS OF MACHINERY AND LABOR

THE economy of power machinery involves operation at or near some particular amount of work which corresponds with the designed purpose of the machine. An electrical motor, a water-turbine and a steam-engine or boiler vary in their efficient use or in their economical output of electricity, water and steam, according to the load they are carrying. At some particular load their most effective results are obtained, and much of the attention of the designer is devoted to the proportioning of the design so as to negative the falling off in effectiveness as the load is varied. Only in a few types of power machinery is a continuous load of one extent to be expected, as in marine engines, where, when once started, the machinery can be operated at a regular rate of power, continuously exerted, and usually that for which it was designed.

Marine machinery, under such circumstances, has shown remarkably high economic performance. War vessels present a much less advantageous situation, since their machinery is required to operate at cruising speeds, and sometimes at excess speeds, varying the conditions very widely.

The causes of variation in economic performance vary with each class of power apparatus, are sometimes complex, and even at this period of scientific advance are not fully determined. In a general way, however, the work of any machine is reduced by fixed losses, such as friction or condensation. These are economically proportioned to the operation of the machine at the best point of its load, but these losses do not decrease proportionately with a reduction in the work, and sometimes increase disproportionately with an increase in the work of the machine.

A water-turbine which is designed for a given condition of water-flow and pressure is at a disadvantage as soon as either element is varied, when its proportions and the angle and curvature of its blades require to be varied to suit the changed condition if its efficient operation is to be maintained. As this cannot be done, it operates disadvantageously under a reduced fall or head, or upon a reduction of the supply of water, and the result is described as a reduction in efficiency, and is usually stated in terms of a percentage of the most effective work it might theoretically accomplish.

The steam-turbine or the reciprocating steam-engine, the motion of which is produced by a more flexible medium than water, can be provided with refinements of regulation, taking advantage of the expansive character of the medium of energy, and the course of ineffectiveness can be modified so as to produce a fair range of variation, within which maximum or nearly maximum economy will be maintained. But such appliances comprise two elements, each of which is affected by the varying conditions, for the steam-boilers, or in the case of gas-engines the gas-producing apparatus, have also their variable characteristics dependent upon the proportions of their duty.

To plan the points of economic development of energy, and to proportion work to machinery, so as to maintain that condition, offers large opportunities for the engineer, and necessarily involves consideration of the elements of work, both as regards extent, character and time, which go beyond the design of the apparatus, and enter the field of the current operating conditions under which the machine is to do its annual work.

In this broad subject the collection of information, or the observation of performance over extended periods, becomes a

Breakdown service renders investment in reserve machinery unnecessary

necessary equipment for the establishment of a basis of understanding. The acquisition of such information becomes a subject of great importance to those engaged both in the design and the manufacture of machinery. It is equally important to those interested in the production and the utilization of energy. It is only by such methods that the prevailing conditions can be established, and the periods during which the most economic performance should be exercised can be determined. Thus, the most economic operation of a machine should be that which is exercised over the longest period, and during other shorter periods it may be operated under comparatively wasteful conditions with greater advantage than to endeavor to secure a maximum economy at a point which in practical operation is little utilized.

Another complication which enters into this problem is that of providing duplicate or reserve machines. These are a necessary accompaniment of the installation of private power-generating plants, which are dependent upon the security of the apparatus for their maintenance. A single machine, a single steam-boiler and a single line of piping cannot be regarded as a secure means of providing continuity of service, since each is liable to minor deficiencies or accidents which may place the whole combination out of operation. It is therefore necessary in such installations to provide more than one, and where two must necessarily be in service at any given period it is customary and proper to provide a third. These divisions may be desirably provided in units which may be better proportioned to the variations of work than would one or two larger units.

It is not uncommon, therefore, to find in large buildings, such as offices and hotels, three, four, five and even more appliances of a given character, some of which can at any one time be in operation, while at all times a certain proportion is idle, but acts as a stand-by or reserve.

The cost of installed capacity in domestic plants is by this means substantially increased, but the element of security is attainable only by such means if the plant is to be the only dependence for the service afforded. Recourse is frequently had to the service of a public supply company in the form of what has come to be known as "breakdown service." This takes the form of a connection of electricity or steam which provides the means of maintaining some necessary or minimum proportion of the service.

The cost is based upon the capitalized value of the power or the volume of the supply held in reserve by the public-service company ready for the convenience of the consumer as and when required.

The cost of such a connection for emergency service is often modified by permission to utilize the connection for the purpose of temporary supplies of energy. These may extend to the value of the charge for the connection, at the prevailing rates for the amount of energy used. Such "breakdown" connections are largely utilized to reinforce the security afforded by domestic installations of machinery, and are of very great advantage to the owners of property in which such plants are installed. This advantage is derived not only from the superior security of the connection, but from the fact that it supplants or displaces the expenditure of capital upon reserve or stand-by machinery of equal extent. The advantage may even extend beyond this point, because the machinery actually installed may, with proper care, be better proportioned to the work which has to be done than would be the case if stand-by or duplicate machinery were required. This service may also be of special advantage in providing service during overtime and night hours when generating apparatus would be operated at undue expense.

Where a "breakdown" connection is not provided, and reserve machinery is installed, the proportion of the available power

In private plants the average annual utilization of their capacity is below fifteen per cent.

which is utilized, or the "load-factor" of the installed plant, is generally very low. In a first-class office-building, in which three generating units are provided, each of equal proportions, during the working hours of typical days of the four seasons of the year, the percentage of load to the power of the engines in actual use is often as low as 27 per cent.; but there are long periods during which the proportion is much lower, such as the off-days of business, Sundays, holidays and Saturday afternoons.

The proportion which the load or output of a plant may bear to an installed capacity, inclusive of the stand-by capacity, is illustrated in the case of a hotel plant having four generating units. In this plant the output ranges between only 12.2 per cent. and 31.5 per cent. of the total available capacity.

In the particular case referred to the equipment was very considerably in excess of any developed requirements for electrical energy, even though these were, as originally designed, based upon the use of carbon lamps for lighting. Under these circumstances, any two of the units more than covered the maximum requirements of the hotel; and regarding one additional generator as a sufficient reserve, the fourth machine became an unnecessary and unutilizable investment. This was due to an excessive estimate or assumption of probable demands for the output of the plant, an error now magnified by the reduced demand for energy due to more efficient means of lighting.

An excessive estimate of the unknown demands of a building for any class of service is excusable.

The effect is, however, disastrous when it results in an investment in unnecessary machinery, which not only has no value as an element of service, but occupies space which it has taken other capital to construct.

A risk of this character is not necessary, where a public service can be secured, because the nature and extent of the demand can be accurately ascertained by a period of utilization of a purchased supply. This course enables the investor to retain his capital until the extent and the value of any investment in machinery are defined by actual experience.

There is nothing to the advantage of an investment in unnecessary apparatus or in machinery of excessive proportions, because both involve, not only a dead loss of capital, but an annual burden of expense in up-keep in the one, and an excessive operating cost in the other.

The time of service has also a material effect on the utilized value of an investment in power machinery. The period of demand in such buildings as those to which reference has been made is very limited and irregular. The night and holiday service of a business building is very small. Even hotel service, for five hours nightly, is on a very low scale. Enough variety of size in machines cannot be installed to meet the variations of such requirements, and those that are operated are often under much disadvantage, owing to the low working load-factor. Of the installed capacity of machinery in private plants the average annual utilization is less than fifteen per cent., and often less than ten per cent.

The same remarks apply in great part to the steam-boilers installed in such plants. In this class of apparatus a substantial addition could be secured under favorable conditions of maintenance by forcing the output of the boilers beyond what is known as rated capacity. It is not unusual nor difficult to obtain a third more capacity from a boiler, when in first-class working order, than that at which it is supposed to operate. Such an excess output, moreover, is not obtained with much loss of efficiency, but rather the reverse. A boiler operated at a small portion of its capacity suffers more than does the same appliance when forced beyond its normal capacity. The reason

In most private plants an excessive amount of boiler capacity is in use

for this lies in the greater heat of the fire, as compared with the prevailing temperature inside the boiler, by which a greater degree of efficiency in heat transmission is secured.

Where draft and furnace conditions are properly handled, most boilers will show a better degree of efficiency above their rating than below it. This over-capacity, however, is not a means of providing for the ultimate security; and in boilers, as in engines, it is necessary to provide reserve appliances, unless a breakdown connection of steam supply can be secured from a public source. The installation of reserve boilers is therefore a usual accompaniment of a private power-plant. This places under the control of the operating force a larger boiler capacity than is really necessary for any working condition, which is frequently an indirect cause of a lack of efficient operation. As soon as a boiler becomes fouled by neglect, and is incapable of maintaining its full output, its deficiency is more readily met by operating another boiler, than by taking the trouble to clean or repair that which is out of order.

In most private plants there will thus be found an excessive amount of boiler-capacity in use, and instances have been observed where the entire capacity of a plant, inclusive of reserve boilers, has been kept in continuous operation for months at a time, all the boilers operating upon work at no time representing an output of more than one-half of their capacity.

Many such installations are so arranged that all the boilers connect to a common steam-main or system of piping. When carelessly operated, the supply of steam from one boiler may be considerably in excess of that from others, and the steam provided by the active boilers may actually be entering the inactive boilers, and there be more or less condensed by radiation.

A not infrequent combination is the addition of a modern boiler to an older set of boilers, as in the case of a plant where a water-tube boiler had been installed alongside two horizontal tubular boilers, and complaint was made that the new boiler consumed an excessive amount of fuel. On examination of the conditions, it was found that there were two smoke-stacks, the damper of only one of which was controlled by a damper regulator. The two smaller boilers were being operated much under their capacity because their damper was constantly closed by the regulator, while the new boiler was being forced by its damper being open, and was maintaining the excess pressure that closed the other damper. It was actually delivering steam into the old boilers, where it was being condensed.

Many instances of lack of proper care and attention to steam-boilers could be recited, but they would only serve to illustrate a prevailing condition by which the care and attention to fuel burned in boilers are frequently left to the least informed class of labor employed in private plants, namely, the firemen, while the engineer, who should be actively interested in every operation in the fire-room, is usually found to be devoting his whole attention to automatic machinery, or to other appliances of minor character.

In a public discussion one authority recently made the statement that the place for the care and attendance of the operating engineer should be upon the fire-room floor, instead of in the engine-room.

Steam-piping is often a source of unobserved and unascertainable losses. The proportions and extent of piping are matters which are settled by the judgment of a designer affected chiefly by consideration of some maximum condition. The proportions thus become excessive for average conditions, and an undue proportion of interior condensation is the result. Interior condensation increases relatively as the rate of flow of steam *decreases*. There is a fixed rate of condensation when no movement of steam is taking place. A recent investigation demonstrated that under normal average operation the condensation in a system of steam-piping in an isolated power-plant was ten per cent. of the total steam generated, but when the total fell to one-half of the average, the condensation was not lessened, but actually increased.

Of all the steam raised in domestic plants, more than ten per cent. provides no useful service

Of all the steam raised in domestic plants, more than ten per cent. must be assumed to be condensed to water, and to provide no useful service.

Economies can be effected in many systems of piping by replacing large pipes with others of less size. It is cheaper to lose a little pressure in limited periods of high demand, than to continue excessive losses by condensation at all periods of service.

In studying the conditions of operation of domestic plants, it has nearly always become evident, upon ascertainment of the facts, that it is the variable demand upon the electrical generating machines which constitutes the excuse for maintaining in operation an excessive boiler capacity. The fluctuations of such loads are shown by such illustrations as that of the lighting demand of a small hotel, in which the little building requires, during the major part of the day, a load averaging only about ten kilowatts, which, after five o'clock, rises very suddenly to thirty-five kilowatts, or three and one-half times the average amount. On a larger scale, a modern New York hotel shows by its electrical load the same sort of characteristics, rising from a low point of seventy kilowatts to a peak, between nine and ten o'clock P.M., of one hundred and seventy kilowatts, or two and one-half times the minimum. Observations showed that this is mainly due to lighting fluctuations. The result of such fluctuations is the maintenance in operation of two boilers when one would, without the electric load, amply suffice for all other services, and would further operate upon a reasonable average load-factor, productive of a higher degree of average economy.

The relation of the cost of labor to the output of electric energy varies inversely with the increase of the product. The larger the quantity produced, the less should be the relative cost of labor per unit of energy, or per kilowatt-hour. Thus the central station costs for this element of operation are always less than can be the case with the smaller private or municipal power-plant.

Owners of some buildings have installed machinery with an idea of adding an element of interest to visitors, or of pleasure in its ownership.

High-class steam-engines and electric dynamos are attractive in their operation, in keeping with the employment of high-class labor, and add an appearance of independence and dignity to the ownership of a large building. The effect of this psychological condition may be seen in some quite elaborate expenditures which have been made in certain private and public buildings, upon electrical machinery and appliances and their surroundings. These are often quite in contrast with a relative neglect of other and perhaps more important and serviceable parts of the installation, such as boilers.

It is not uncommon to find a very substantial capital expenditure upon ornamental details around electrical switchboards, upon tiled floors, wainscoting and lighting of engine-rooms, and particularly in the allotment of unusual proportions of building space around and above electrical machines, even extending in certain buildings to the provision of visitors' inspection galleries.

To some extent, therefore, the circumstances surrounding the installation of electric generating machinery differ from those of such rather commonplace appliances as boilers and pumps, and seem to interest the owners of private properties to the extent of a willingness to expend money on appearances, apart from their cost or their commercial value. The same effects extend to the employes of such plants, to whom the engine-room, with its swiftly-moving machines, is usually the central object of their interest, and the place upon which their time and attention are mainly concentrated.

High-speed and high-pressure machinery is sensible to derangements and liable to destructive accidents

It is doubtless a pardonable pride in appearance which leads in part to this effect, but there is also a practical necessity for this attention, inasmuch as electrical machinery operates at a higher speed than other appliances in common use in buildings, and is of a more generally delicate nature. While the operation of steam-engines and generators has been, by modern methods, rendered practically automatic, this result has nevertheless been accompanied by a higher degree of complexity and sensibility to derangements, and accidents are liable to occur with electric generators, the nature of which may become extraordinarily destructive, and may result from a small degree of inattention or carelessness, which in another class of machine, such as pumps, would be productive of little evil effect.

Many accidents have occurred to high-speed engines and generators, the causes of which have presented difficulty in determination. Upon investigation, these may generally be traced to one of several prevailing causes. The entrance of water to the cylinders of swiftly-running reciprocating engines, especially those of high economy, in which the clearance spaces at the end of each stroke are limited, has been destructive to a number of engines, and has taken several forms of wrecking the machine.

In a modern business building, the entrance of water, brought about by the rather too hasty opening of a valve between two boilers, resulted in driving the rear end of the cylinder off the engine, seriously injuring an attendant. As this is the weakest part of cylinder construction, such a result probably represents the least destructive form of the action of water in the cylinder. If the water becomes trapped in the head end of the cylinder, the strength of parts is usually such as to prevent a breakage of the cylinder, but the effects are transferred to the crank-shaft, which, being suddenly arrested in motion, suffers breakage, or if the shaft does not break, the effect is transferred to the swiftly-moving fly-wheel.

In an accident in a prominent New York hotel the bursting of the fly-wheel of an engine was probably brought about by this cause, and a large amount of destructive effect upon the building resulted, fortunately without loss of life. A cause for accidents of somewhat similar nature, generally resulting in the breaking of the crank-shaft itself, is found in the disarrangement of alignment of the crank-shaft bearings. In another hotel this cause brought about the fracture of two engine shafts, both of which broke off very close to the crank-arm. The exactness of shaft alignment is an essential feature in the up-keep of such engines, not only on account of the possibility of bending the shaft at some point at every revolution, but also because the generator may be allowed to approach too closely to the poles of its field magnets on one or other side, and thus produce a serious drag upon the shaft in one direction.

In a laundry building a piece of rag drying outside the building was blown through a basement window into the governor of the engine, which then raced and drew water over from the boiler, and was completely wrecked.

The proper balancing of heavy fly-wheels is also a matter of great importance, and even the undue size of a fly-wheel may, as has been the case in certain instances, contribute to its eventual destruction. The operation of two or more such engines in parallel upon an electrical service unites through the switchboard the operations of each individual electric generator, and a watchful care is necessary in order to prevent the pressure developed by one dynamo exceeding that developed by another upon the same circuit. If, for any cause, the speed of one generator is temporarily interrupted so that the pressure or voltage falls, there is a liability that the flow of the electric current may reverse, and the slackened generator may become reversed and be operated as a motor by the current supplied from the other machine.

In some isolated plants it is not a source of economy to reduce the electric load

Such occurrences have taken place in certain instances, and particularly with the type of generator operated by steam-turbines, in which the possibilities of reversal are greater than in the case of a crank and fly-wheel engine. These mishaps have led to the introduction upon their individual circuits of protective appliances on the switchboard, designed to break the circuit upon a reversal of the flow of the energy.

There is probably no part of the machinery employed in private or in central station plants that has received the amount of detailed attention, in the direction of improvement, that has been devoted to the design of the steam-engine. The development of the high-speed automatic engine is one which was brought about in this country, based upon the work of Charles Porter, and the automatic control of such appliances has been wonderfully improved by the inventions of Rites and Ball.

Not only in large-sized engines, but in quite small machines, great advances in the direction of control and economical operation have been made in the past twenty-five years, and the process of compounding the use of steam has been applied even to little engines operating generators of less than one hundred kilowatts capacity. The result of this process has been to place at the disposal of private plants a wide choice of types of engines suited to the operation of electric generators by direct connection to them, so that both engine and generator rotate at the same speed.

In addition, a range of sizes has been developed by a number of manufacturers which offers the opportunity of proportioning the installed capacity of a plant by dividing it into several units of a capacity which will accord with certain expected or developed loads, under which the machine may operate at the best advantage. It thus comes about that most private plants are found to be equipped with several engines and generators, the sizes of which are varied.

If this has not been done, there is difficulty in meeting the changed conditions due to the prevalent decrease in domestic demands for electricity in lighting, brought about by more economical forms of lamp. In some cases it has not been shown to be a source of economy to reduce the electric load in this manner.

The use which is made of generating machinery is limited by time demands to a small proportion of the yearly period of 8,760 hours.

The work of heating in the climate of New York occupies from 3,000 hours to 5,000 hours. Elevators in business buildings operate for 3,000 hours, and in apartments and hotels from 5,500 to 6,200 hours. Lighting in business hours does not exceed 3,000 hours, and when continued in night service covers about 4,000 hours. Domestic operations, such as cooking and laundry work, occupy about 2,000 to 3,000 hours.

Machinery installed for these purposes has therefore a limited period of utilization, ranging from thirty-three to sixty-six per cent. of the time, and being idle for similar periods. During its active operation its demands for heat or energy are not constant.

The serviceable use that is made of the investment of machinery in isolated plants is thus but a small part of its capabilities.

CHAPTER IX

HOUSEHOLD POWER-PLANTS

Several alternative forms of power, other than steam, may be economically used

HOUSEHOLD POWER-PLANTS

THE utilization of energy in a modern building takes various forms, but can be grouped under a limited number of necessities or conveniences provided by heat or power. In the order of need, they may be stated as follows:

Sanitation, including water supply.
Heating and hot water.
Lighting.
General power purposes, such as elevators.
Refrigeration.

General power would include the operation of other motor-driven apparatus, such as ventilating fans, cleaning by vacuum pumps, and other minor operations, most of which in these days are or could be conducted by electrically operated devices.

Taking up these subjects in the order presented, we shall find that power in several forms could be applied to them. Thus it would be possible to effect heating and lighting by the direct use of gas, and lighting and power could be effected by the use of electricity. Oil, either burned or gasified, could effect all of these purposes, but for certain inherent disadvantages. The most generally adopted method, however, is the utilization of steam for such purposes as heating and hot water, and the developments of recent years have led to the economic substitution of electrical energy for other methods of lighting, of pumping, of operating elevators and other subsidiary services, both by reason of its convenience, its small requirement for attention, and its constantly reducing cost.

The economy of the operation of household power machinery mainly turns upon the raising of steam for the purposes of heating and hot water, and the question as to whether steam shall also be employed to operate pumping and power machinery for other services, or alternatively to operate electrical generators, which in turn shall distribute the energy to other mechanical services. The value of any service thus provided is represented by the cost of equivalent service provided by other methods, or secured from some public system.

A complication is introduced into this simple comparison. It is, whether any part of the steam which is utilized in operating machinery, such as electrical generators, can be utilized in some secondary process, such as heating, so that its product can be regarded as a "by-product." This question is generally directed towards the work of heating buildings, and it may be assumed that steam, thus secondarily utilized, could to the extent of its value reduce the total cost of the services to be rendered by a plant.

Some of the limitations which surround this feature of the re-use of steam have been described. Physical limitations are brought about by the varied conditions of latitude and climate in which a plant may be situated. In the City of New York this question has been brought into the controversial field to an unusual degree by reason of the fact that it has been used as the main argument for the maintenance of household or "isolated" plant operation, both under municipal and under private management, as opposed to the purchase of public services of steam, gas or electricity from enfranchised corporations.

Steam as a by-product is an economic element in the question of total cost of operation of a building, but it is not, as has

The value of exhausted steam has been exaggerated by advocates of household plants

generally been asserted, a means of the reduction of cost of one of the services or products to the disadvantage of others; in other words, this feature has been utilized according to the point of view of the person engaged in argument, both for and against the value of the commodity in which the party may be interested. It has followed, not unnaturally, that the net value of the element in question has been lost sight of in the controversy, and some of the most ardent advocates of the operation of household plants have so exaggerated the value of exhausted steam as to create an impression that it was a major feature in economic combinations.

It is, however, only necessary for any impartial inquirer to look into the surrounding circumstances in order to observe how restricted must be the value of exhausted steam as a heating agent. In the climate and under the atmospheric conditions of New York, the heating season does not extend for a longer period than 5,040 hours, or about fifty-five per cent. of the year. This period includes variations of temperature ranging from a low point, somewhat above zero on the Fahrenheit scale, to a temperature of seventy degrees, at and near which no interior heating of a building is required. The average requirements are also affected by the circumstances of the utilization of a building. Thus, a business building which is occupied only about ten hours out of the twenty-four, and is closed entirely thereafter, does not require the same amount of heating during hours in which it is closed as during those in which it is occupied. Inversely, a residential building may require a maximum amount of heating during an evening period and a less amount during the hours of the day. Business buildings can be and are being heated satisfactorily by the use of heat during only three thousand hours per season. The warming of a building at the beginning and at the close of the heating season involves very much less than the average amount of heat required. At such times fuel is often burned to very little advantage, and labor is wastefully employed.

The climate of New York is peculiarly favorable to economy in heating, as there is a large amount of direct sunshine during the winter season. The heating effect of the sun's rays, acting upon the exterior part of a building, retards the loss of heat. Humidity also reduces the extent of heat required.

Wind is found to have a substantial effect upon the need for interior heating when the temperature is low. It might be much less of an element if the proprietors of buildings recognized the economic value of double window sashes, such as are utilized in colder climates. The fitting of window-frames and the construction of sashes are generally defective, and result in air leakages around the brick opening, as well as at the sash joints and meeting rails. The use of improved forms of weather-strip, particularly the metallic, is a source of substantial economy in the use of heating steam. As much as fifteen per cent. reduction in installed heating surface and twenty per cent. in fuel may be saved by their use. Where buildings are in protected situations, the movement of wind does not affect to so large an extent the consumption of fuel for heating.

The average temperature of New York City is about forty degrees Fahrenheit during the heating season, which extends over about two hundred and ten days, and the interior part of buildings has, therefore, to be maintained at only about thirty degrees in excess of the average exterior temperature. The use of steam is found to follow temperatures, because occupants naturally control the supply to suit their individual convenience, and overheating of interior space is as inconvenient as lack of heat. Now, unless exhausted steam can be supplied from steam-using machinery, in a volume according with the requirements of the heating apparatus in following the atmospheric variations, the steam will either be short of the requirements at one time, or in excess of them at another time. In such cases its value will not be in excess of the proportion which can be utilized. This value must be that which is established by a supply provided in some other manner and proportioned to the varying needs.

Exhausted steam can never be supplied in a volume according with the requirements of heating

As a matter of practical operation, no steam-power engines, unless they be very much larger than the ordinary needs of city buildings require, can furnish all the steam required at all times by the heating system of the building which they serve. On the other hand, very few power-plants are so small as to emit at all times less steam than is required for the minimum heating of the building they occupy. Some live steam is therefore required from time to time to fill in the discrepancies between the exhaust of the power machines and the coincident needs of heating. And in the same way there is at other times an excess of exhausted steam passing to the atmosphere.

That this is the case is more apparent when it is considered that no buildings are continuously operated during the twenty-four hours of the day at the full capacity of their interior services. Even a modern hotel has a period of six or seven hours daily when practically every service is either closed down entirely or is maintained at a very low minimum. This inequality is further aggravated by the variation between the natural demand for lighting and that for heating, the two of which do not synchronize.

The largest requirements for lighting in business and residential buildings are in the evening, while the lowest temperatures, and therefore the largest heating requirements, are always in the earlier hours of the day.

An example of an economical combination is the mechanical plant of an office-building in which there is no electrical generating apparatus, the elevators being operated by steam-pumps. A large proportion of the exhausted steam of these pumps is utilized for the major part of the heating season, the balance being made up when and as required by live steam generated in the boilers by the labor of a reduced staff of employes. There are occasions during the beginning and termination of the heating season when even this moderate supply of exhausted steam is in excess of the heating demands. Elevator service is in this building a partial by-product of heating work.

The fluctuations of heating requirements have long been studied by those in charge of public systems for the distribution of steam and hot water, and much valuable information has been acquired upon this phase of the subject. The demands of buildings of diverse character produce a variable average demand of much interest.

In the two cities of New York and Detroit, during the season of heating, the monthly proportion of the consumption of steam in the buildings supplied by public steam-distributing systems varies in the following proportions of the total output for the heating season:

Month	New York	Detroit *
October	3.1%	6.6 %
November	7	12.15
December	15	15.75
January	25	18.15
February	22	18.7
March	20	15.45
April	5	8.7
May	2.9	4.45

It will be noted that the characteristic of the milder and more variable climate of New York has the effect of reducing the proportion of demand to about half that of Detroit at the beginning and end of the season.

* Mean of two companies.

Steam used by auxiliary apparatus reduces the value of exhausted steam from other engines

The use of exhausted steam is not free from effects which discount its value at its source.

The operation of heating systems by exhausted steam involves a certain pressure retarding the exit of the steam from engines and pumps. This is necessary in order to force the steam into and through the heating pipes and radiators.

This brings about the condition in the engine which is commonly described as a "back-pressure," which may vary up to several pounds per square inch, and to that extent resists the movement of the engine and detracts from its power.

It becomes necessary, in order to overcome this resistance, to apply more force to the engine, or, in other words, to raise the pressure supplied to it; or if that cannot be done, then to provide it with more steam to an extent which will counterbalance the resistance set up on the exit side of the piston by the back-pressure. Automatically controlled engines effect this result by the admission of more steam through gear which delays the point of cut-off. This process is therefore visible only at the boiler, or rather in the coal consumed, and is not readily determinable, except by comparative observations.

Many ingenious devices have been developed by which this "back-pressure" may be reduced. These take the form of accelerating the movement of the steam in the heating season by suction apparatus, such as the well-known "vacuum systems." The use of steam-driven appliances, such as vacuum pumps or ejector jets, is thus involved, the steam consumption of which may be in some cases turned into and partly utilized in the heating system,—displacing, however, the utilization of an equal amount of steam exhausted from other engines. Wherever there is an excess of exhausted steam available for heating, the steam used by auxiliary apparatus thus becomes a reduction of the utilizable part of the exhausted steam of a generating engine or power pump, and its value as a source of ultimate economy is subject to this deduction. The steam used in circulating apparatus, as described, will vary from two and one-half to fifteen per cent. of the heating steam. Steam used in producing a suction by ejectors on air-line systems is, of course, entirely lost. The use of exhausted steam in this way is not all clear gain.

The effect of a back-pressure upon steam-engines varies with their type and proportions. It must not be confused with what is known as "compression." Compression is a process of an economic character, consisting in enclosing or cutting off the exit of a portion of the undischarged contents of an engine cylinder, and thus causing the enclosed or entrapped vapor to be compressed in taking up the momentum of the reciprocating working parts of the machine. This beneficial process is interfered with and negatived by a back-pressure, when the vapor enclosed becomes of greater density than is required for the purpose described, and excessive compression results, which to that extent reduces the effectiveness of the engine. It is very difficult to predetermine the effects of back-pressure on an engine unless the full details of its construction and control are known; but, roughly speaking, the statement published by Whitham may be accepted as an indication, namely, that "one pound back-pressure on an engine is a fuel loss of about 2½ per cent."

The effects of a back-pressure are very marked upon the operation of direct-acting reciprocating pumps. These depend, for their full stroke, upon a fixed entrance, cut-off and exit of the steam, and particularly upon a terminal pressure in excess of the opposed load or resistance. This is usually required to be about thirty-three per cent. in excess, in order to secure the movement of the piston and other reciprocating parts to the full extent of the stroke. Any falling off in the pressure, or any increase in the resistance at the exit side, brings about a

The use of exhausted steam is not all clear gain

shortening of the stroke. Then, upon reversal, live steam is admitted uselessly to the vacant spaces at each end of the cylinder, and this increases the total use of steam for any given duty.

The curious result, therefore, of the operation of such appliances under back-pressure is that as the latter is increased, so the total steam used is increased. The effect becomes cumulative: increasing steam needed for heating, requiring increasing back-pressure for circulation, may involve an increasing total volume, and as fast as the by-product increases, so may the wastage of surplus steam increase.

CHAPTER X

LIMITS OF HEATING WORK AND VALUE

The full capacity of heating systems is rarely utilized

LIMITS OF HEATING WORK AND VALUE

A REALIZATION of the necessity for the investigation of the details of individual operations led to the study of the conditions obtaining in individual buildings, during a period of years, and the gradual ascertainment of the controlling elements, some of which were readily determinable, others with a much greater degree of difficulty. One essential point first determined was that for any class of building the average condensation of steam in a house-heating system is less than the maximum capacity of the heating system, a condition which also applies to each individual radiator. The maximum condensation in each comes into operation only when the most extreme climatic combination of low temperature and adverse wind is in existence.

Research into past records and observations of present operation showed that the full installed capacity of an interior heating system is utilized only for about eight days out of the year in New York; and, further, that during those eight days the maximum is in operation only for a few of the early hours of the day. The average use of steam in such heating systems for any class of building closely follows the variations between the fixed interior temperature of seventy degrees and the outside temperature, practically irrespective of the movement of wind.

The quantity of steam used at any time in a heating system in business buildings is that corresponding to the average temperature; or, in other words, it bears the same relation to the maximum requirements as the average temperature does to the worst temperature condition, commonly referred to as zero.

Thus it becomes practicable to determine in advance the maximum heating requirements, and also to estimate very closely the fuel required for the heating of any building for a season, or for any month in that season. Due allowance, of course, is made, in connection with such determinations, for seasonal fluctuations. These are usually to be found, for the particular locality, in great detail and accuracy in the records of the Weather Bureau.

As the work of heating buildings closely follows the variations of exterior temperature, the records of those maintained by the public authorities become of interest to the economist. In New York the averages of forty years' recorded hourly observations are as follows:

CITY OF NEW YORK

Month	Mean temperatures, degrees Fahrenheit	Difference to 70 degrees	Per cent. of total difference
October	55.4	14.6	6.9
November	43.9	26.1	12.43
December	34.2	35.8	17
January	30.8	39.2	18.6
February	30.6	39.4	18.7
March	37.3	32.7	15.5
April	48.8	21.2	10.1

The establishment of the net extent of heating a building places a limit upon the value of any contribution towards this work. If a building can be heated by hot-water circulation or by what is known as low-pressure steam, raised for the special purpose, and involving no machinery other than a boiler operated by moderately skilled labor of proportionate extent, with the least possible wastage of water, cost of removal of ashes, and expense in up-keep and repair, then any contribution or by-product of steam from a power-plant can have only this value.

No harmonious interrelation exists between lighting, power, and heating work

If an exhaust-heating system involves the use of some addition of live steam, the value of the exhaust is only that of the alternative method less the cost of the live steam supply.

The service of electric light also varies in period and quantity by natural causes, but of a different character to those affecting the work of heating buildings.

Lighting during the daytime follows the extent of cloudiness of the period of the year and the intensity of direct sunshine. The intensity of light for a given period of any day, even with an equal degree of clearness of the atmosphere, will vary as between seasons. The use of artificial light follows these fluctuations to some extent.

Elevator service also varies by period and demand. In business buildings it is limited by business hours. Its extent varies according to traffic, which is affected by seasonal changes of occupancy and by business activity or slackness.

From consideration of the varying elements affecting the operating services of modern buildings it must be evident that no possible harmony of interrelation can be established between the lighting, the power and the heating work, and that the most that can be hoped for is some partial reutilization of the product of the one to the advantage of the other.

In a number of instances it has been found to be the case that of all the steam consumed by a power-generating plant in a modern business building approximately one-third may be capable of reutilization in the form of low-pressure heating. But this statement does not contain the whole of the facts, because underlying such reusage of steam lie the primary diversions or wastages that accompany the use of the steam by the machinery and of any appliances required to promote circulation in the heating system. These need form no part of the operation of steam-heating if it were conducted under what is known as a low-pressure system.

In such a system steam is raised to a moderate pressure, circulated through the heating system, condensed and returned automatically to the boiler in the form of hot water. Nothing is required in the way of operating machinery involving the use of steam, and the necessary attendance is confined to the class of fire-room labor; while repairs and up-keep, investment and fixed charges, are all on the lowest scale.

The cost of labor is immediately increased when steam under high pressure is generated. Municipal regulations usually require the presence of licensed engineers and firemen in premises in which steam is maintained at a pressure exceeding ten, fifteen or twenty pounds per square inch.

So soon as the use of exhausted steam is introduced into such a system, complications follow in rapid succession: the pressure available must be reduced to that which will not adversely affect the running of the engines from which it is derived; the steam under such circumstances usually requires accelerating apparatus to aid its circulation or to return its condensation to the boiler, involving the use of appliances which in turn demand skilled attention; and the boiler from which steam is generated in part for the plant and in part for the heating system is now operated at high pressure, requiring the diversion of part of the steam generated to operate feed-pumps, drip-pumps, and other auxiliary apparatus, all also involving skilled attention.

Part of the water heated in the boiler is discharged as "blow-off" to waste. The steam which is generated is then passed through a system of piping, in which its pressure is generally reduced, and on its way part of its volume is condensed to an extent which, being unseen, is but little realized. It has amounted in actual observations, under favorable circumstances, to from 5.6 to 17.9 per cent. of all the steam raised.

When these considerations are applied to the operation of heating by exhausted steam, the process is found to be much depreciated in value. Its extent has been found to be limited, under New York City conditions, to about 30 to 33 per cent. of the total generated. This may be reduced, by additions of apparatus involving the use of other steam, to an extent of from 2½ per cent. to 15 per cent. of its quantity. The net effect must be studied in connection with the whole costs of operation of an isolated plant.

Energy used to light or ventilate machinery spaces is unproductive

The matter may become clearer by considering it from the point of view of some part of the electrical output being a by-product of the steam which has passed through the engine and has effected part of the work of heating the building. The subsidiary requirements or wastages which accompany the operation of the engines now come into consideration, such as steam used for the purpose of the operation of auxiliary apparatus necessary to the engines, which would not exist if the heating were done by low-pressure steam supply and the engines eliminated. The cost of all such accompaniments are deductions from the value of the secondary usage or by-product. Moreover, any part of the product of the engine, such as electricity, used for ventilation or lighting of the machinery spaces, is a deduction from the value of the product.

A plant of electric generating engines provided the electric light and power of a group of city buildings, the total electric output of which was found to consist of 83 per cent. usefully utilized and 17 per cent. used in lighting and ventilating the engine and boiler spaces and productive of no part of the services provided by the plant.

This work was accomplished by the use of steam in the following manner:

	Lbs.
In the piping there were condensed	5,371,850
In the feed and other auxiliary pumps	5,402,060
In the engines	36,275,350
Total	47,049,260

Of this amount there were utilized in heating and exhausted steam the following:

	Lbs.
From the feed and other auxiliary pumps	2,705,125
From the engines	10,570,900
Exhaust or by-product	13,276,025

—which is 28.2 per cent. of the total generated for this purpose.

The electric output might therefore be considered a by-product of heating steam to the extent of 28.2 per cent. of the total energy generated. But 17 per cent. of that was generated only to be used up in the interior operations of the plant, and thus the net effective by-product was only 11.2 per cent. The expenditure of 6,193,000 pounds of steam was involved in condensation in piping and in the operation of auxiliary appliances in order to make practicable the operation of engines which actually afforded 6,866,526 pounds of exhausted steam to the heating services. This shows that the result of passing live steam through electric generating engines, in order to produce electricity as a by-product of the use of the steam in heating, is not an appreciably economic process from the point of view of fuel or steam only. The result would be greatly to the disadvantage of the process if the cost of labor and up-keep of the engines were brought into consideration.

The greatest economy can be effected at the source of production

The operation of an idle engine, or even of an artificial load on an engine, has been sometimes advocated in order to supply steam to a heating system. Such a method is based on misconception of the circumstances. The steam supplied to an engine costs some addition to its quantity, by reason of the losses in the piping, and by the operation of the necessary auxiliary appliances such as feed-pumps and drip-pumps, and also by direct losses in the cylinder of the engine.

The condensation of steam in mains and branch piping may be from as low as one and one-half per cent. for the connections of a single machine to as high as eighteen per cent. for a group of apparatus. This is steam which has merely been raised to be condensed again, without doing any work. The operation of feeding apparatus and drip-pumps will use from five to ten per cent. more. Of the gross total, therefore, but a reduced quantity reaches the engine.

Thus a waste product cannot be utilized to advantage if its use involves undue expenditures in the machinery or process in which it is to be utilized, or adds to the cost of the primary process of which it is the result.

Some misunderstandings of this nature apply to the use of exhausted steam in the process of refrigeration. Such systems are widely advertised, and contribute to the impression that exhaust steam in large engines can be so utilized. In reality these are closed systems, utilizing, under considerable pressure, the exhaust of their own auxiliaries, such as ammonia, circulating and feed pumps. To these are sometimes added the exhaust of other minor auxiliary pumps in a combined plant. The result is fairly economical, though the high back-pressure required involves the wasteful demand for steam in the pumps which has been already described.

Experiments in the use of the exhaust of reciprocating and rotary engines on such services have usually been economic failures, due to the high pressure and temperature required in the process.

Condensation in steam-cylinders varies from twenty to forty per cent. of the steam supplied to the engine or pump.

This cylinder condensation is generally thrown to waste, as the water is fouled by cylinder oil and cannot be re-used in the boilers, while pipe condensation is usually returned, through return pumps or traps or other devices, to the boiler.

The steam emitted by a non-condensing engine for use in heating work is therefore always substantially less than the amount it actually receives; and it is, besides, of less heating value, for it contains less heat per pound weight than the steam which could have been supplied direct to the heating system. To assert, therefore, as is done by some enthusiasts, that it is an economical process merely to pass steam through engine cylinders for the purpose of heating, is to ignore palpable facts that contradict any such possibility.

Only when the product of the engine can be utilized for some definitely useful purpose, can such a process contribute to economy. Yet in a recent paper one such enthusiast recommended the operation of antiquated and wasteful engines, on the ground that the heating system needed their steam. It did not appear to be perceptible to him that even if the output of old machines were utilizable, the exterior losses accompanying their operation would be deductions from any apparent economy. Beyond all this stands the absurdity of operating any engine or machine unnecessarily, adding to its up-keep cost and reducing its operating life.

Usually, greater economies can be effected nearer the source of heat-production than by the use of by-products at the tail-end of the procession of expense. More can be saved by reducing labor, or by improving the wasteful operation of boilers, than can be gained by the use of part of the exhaust of the engines or pumps operated. Economy, like charity, begins at home. An unvarying source of expense in domestic power combinations is labor. Fuel may vary according to demand; labor rarely does so.

Economic refinements that involve capital investment are often of uncertain value

Economic refinements that involve capital investment are of uncertain value. Microscopic attention to detail at the small end of affairs produces apparent effects, which may be discounted by additions at the fundamental point of operation.

CHAPTER XI

THE LIFE OF MACHINERY AND LABOR

The fact that an old machine continues to operate is no evidence that it is justifying its existence

THE LIFE OF MACHINERY AND LABOR

ASSERTIONS are sometimes made as to the life, or rather the continued existence, of machinery, which are utilized as illustrations of its durability, and are even offered as demonstrations that there is no need to provide for its financial depreciation.

Instances have been advanced of the long-continued existence of certain antiquated power-generating machines, from which a conclusion was derived that the amount of money required annually to provide for the depreciation of such machines should be very much lower than it has been customarily assumed to be.

Such illustrations, apart from their individual weakness, are merely catalogues of instances in which machinery of an antiquated character has been, for some reason or other, maintained in operation for an unduly prolonged period of time, generally at a continued loss. Such illustrations of ancient machinery could be multiplied indefinitely, but no one of them would prove anything except the fact that some circumstance had prevented the proper termination of their existence. Handpower derricks, erected in the eighteenth century on old docks in England, were found at the end of one hundred years of existence to be in serviceable operating condition. Upon such a circumstance might be founded an assumption of the value of such machines which would lose sight of the fact that they had long outlived any commercial usefulness, and should have been replaced several times over by progressively modernized apparatus, the lack of which had probably cost the proprietors the value of the old appliances many times over.

These considerations apply particularly to machines for the generation of power, which is a commercial product: to avoid loss they must be maintained in modernized condition or supplanted by more efficient apparatus. In other words, the fact that a machine continues to operate at the end of a given period of time is no evidence that it is justifying its existence. It is not the mere extent of any physical deterioration which governs the amount of depreciation it has suffered. If a machine is not economically justifiable, it has already depreciated, however limited may have been its use. If it still paid to use antiquated machinery, vast quantities of appliances now discarded would be in service to-day. The difference in the cost of output between more efficient apparatus and existing machinery is always chargeable against the value of the operation of the latter. The deficiency capitalized is the extent of the reduction in the value of the appliance. A difference may exist between the steam consumed by an old and wasteful engine and generator and that consumed by a newer and more economic type, of as much as 40 pounds of steam per kilowatt-hour of output. At a price of $3 per ton of coal on 3,000 hours of use, in one year, an average output of 100 kilowatts represents a loss of $2,250, which represents ten per cent. interest and depreciation on an investment of $22,500, which is more than the value of a machine of that capacity.

It does not even suffice for a machine to be in what is described as "serviceable" condition, for that may not mean a commercial condition. The experience of those interested in the financial results of power-generating machinery is generally in the direction of an extremely conservative estimate of the probabilities of existence, with a liberal allowance for its decrease in capital value within a reasonably short period of

The physical processes which end in depreciation are seldom as rapid as the economic

time. This period may or may not be reached before the physical wearing out of the machine has arrived at a point at which it becomes no longer actually capable of operation. Similarly, a man may be in perfect health and strength, but a machine can do his work better and cheaper, and so hand labor is no longer economical.

One of the characteristics of American industrial development has been the ready willingness of the manufacturer to recognize such limitations of existing machinery, and to replace apparatus, however expensive, by others productive of more effective or more economical results. Instances of such radical rejection of apparently serviceable machinery, and its replacement by more modernized appliances, are too numerous to need extended reference. It was such practices that built up our national steel trade, and that such enlightened methods are recognized to-day is illustrated by the recent replacement of half a million dollars' worth of modern lamp-making machinery at the works of one company.

The subject of depreciation has been greatly misrepresented, because depreciation, which is a financial result, has been confused with obsolescence, which is an economic process, and with deterioration, which is a physical condition. Either of the latter brings about depreciation, and the physical process rarely happens to be more rapid than the economic. An illustration of the processes involved is that of the physical deterioration and economic obsolescence of a work-horse, the capacity of which is definitely connected with its condition, and the value of the labor of which is discounted by its up-keep and by the cost of its supplies or feed. Its age is productive of reduction of capacity, but this process may be, and often is, anticipated for commercial reasons by its supersession by some other form of apparatus. The horse may be in ever so good a condition at the time when the motor displaces it, but its financial depreciation then is complete, for it could be maintained only at a loss. All the elements which come into consideration in connection with machinery will be better understood if considered in relation to such an animal, the life of which may readily extend beyond the point at which its commercial value has terminated.

An element which most directly affects the physical condition of installed machinery, particularly high-speed engines, and therefore contributes towards a reduction of their effective existence, seems to be that of reversals of motion. The nature and extent of such reversals, and, above all, their repetition within a given period, will determine to a large extent the life of a machine. This consideration, of course, assumes that the design of the apparatus has provided ample strength of parts, and does not fail by actual fracture.

A lesser element of the same nature is that of irregular loads or demands for the exertion of energy, which, if aggravated, assume the nature of a shock. An underlying feature is that of the extent of usage, which, of course, may modify either of the foregoing circumstances. Consideration of these matters may eventually form the basis for a systematic appraisal of the probabilities of life, or average of the risks, which would provide a method for insurance of the life of machinery.

These and other features appear to follow much the same course as the causes contributory to the shortening of human existence, and may be stated as follows:

ELEMENTS CONTRIBUTORY TO REDUCTION OF PHYSICAL LIFE OF MACHINERY

1. Exterior or movable apparatus.
    - Abuse.
    - Neglect.
    - Temperatures.
    - Oxidation.

Deterioration of machinery is only partly counteracted by maintenance, up-keep and repair

Irregular shocks in use, such as starting or braking, also road or rail defects.

2. Installed operating and generating machinery.
   Reversals, increased by rapidity and aggravated by shock.
   Irregular loads or service, aggravated by speed and sudden character.
   Excessive usage, resulting in increase of temperature of parts.
3. Fixed equipment, including boilers and piping.
   Excessive and irregular strains.
   Interior causes of decay.
   Chemical action.

—all these being of greater or less effect according to the time of daily usage and lack of periods of rest.

So much misunderstanding seems to exist as to the conditions which apply to the course of existence of mechanical appliances, particularly steam and power generating and utilizing apparatus, that it may be well to examine their nature. The operation of machinery always tends in the direction of age and therefore gradual deterioration, but this is not necessarily at the same rate as, and is generally much slower than, economic obsolescence. The effects of usage and of age, referred to as "wear and tear," "wearing out," or "deterioration," are partly counteracted by the processes of maintenance, of up-keep and repair, which are as necessary in the case of human labor as they are in that of machinery. But these always fail to a certain extent in arresting the full effects of age, and never fully meet the economic changes which affect the machine through causes entirely unconnected with its existence.

Maintenance is a process of continuous attention to, and supply of, operating necessaries, including solicitous observation of the condition of the object cared for, corresponding to the protecting shelter, clothing and food supplied to living beings, in order to maintain their functions in operating condition. It includes supplies which form part of the food of the appliance. Part of the labor in attendance on machinery is involved in this element of its care.

Up-keep is a course of partial re-creation, involving the expenditure of time and money in anticipating causes of decay, of failure, or of possible injury to the object under care, corresponding to hygienic and recreative methods, often involving considerable expenditures without apparent direct results, which are or should be followed in safeguarding the general health and strength of human beings. Thus, welfare and recreation of employes is a justifiable expense of an industry. It is part of the cost of up-keep of the human machine.

Repair is the course of partial reconstruction, replacement, or renewal of worn or of injured portions, after the necessity therefor becomes apparent, and, unless brought about by accident, the need for the process is due to the failure or inability of maintenance, and also of up-keep, wholly to arrest the progress of decay by age or continued use. Provisions to preclude accident or to cover the cost of its results are part of the cost of repair. Health insurance of employes is a repair cost paid in advance.

Deterioration is the physical result of the natural and inevitable insufficiency of the foregoing processes of maintenance, of up-keep and repair, all of which are dependent on human agencies, and chiefly on human observation, wholly to forestall the effects of wear and tear, of age, decay or accident. It is what we see as the accumulated results of neglect, injury, ill health, and age in human beings.

Obsolescence is a modern term designed to fill the vacancy between all those physical elements and those economic causes having similar effects. It is the reduction in the commercial value of the machine, due to the progress of science or the development of the arts resulting in rendering the particular appliance obsolete and commercially valueless. It is equivalent to the substitution of some better, more modernized, or more economical appliance, or may represent the supersession of the machine or of its process, or the reduction of its duty or output, by some other method of accomplishing its results or of securing its equivalent. The term thus covers the antiquated and out-of-date result of the irresistible march of modern invention, and of changes in industrial methods and habits. It is far and away the least calculable in advance, and is therefore the most uncertain, as well as being the most deadly, of the threatening elements which surround the investment of money in machinery as well as the employment of labor thereupon. Obsolescence is applicable also to the labor employed in the operation of machinery. Some alteration of the conditions under which the appliance was originally set in operation and the workman employed thereon may come about as a result of exterior causes, bringing about a lessened value for the labor required in its attendance.

Progress of science may render a machine useless, supersede its process, or reduce its duty

Such circumstances are sometimes entirely beyond the control of a man, but result in his being superseded in his employment by another, perhaps more efficient person, in losing a position by changes in method, or in rendering his work no longer necessary or of the same value as in the past.

The steam-pump has been largely supplanted by the electric pump, which has mechanical advantages, such as quietude and ease of regulation, which would warrant its operation at greater cost; though it is often cheaper to operate than a steam-pump because of the lessened attendance it requires. The use of an electric pump which would displace others having a need for steam, in combination with some other changes, might eliminate the use of steam in a building altogether, perhaps for all or for a part of the year. By a change of method of this kind, labor being reduced, it may become economical to purchase steam for heating, even at a higher unit-cost, or perhaps to generate low-pressure steam only for that purpose, the combination thus immediately reducing the capital value invested in the construction of a high-pressure boiler to that of a low-pressure boiler.

Thus, the obsolescence of machinery may be brought about by exterior causes or economic combinations, just as the health, the vigor and the energy of a man may be discounted or rendered inoperative by exterior circumstances. The machinery may be perfectly new, even economic of its kind, when a new process or a different method or a better machine discounts its value, or destroys its continued usefulness or the commercial value of its output.

There is a form of obsolescence which is rarely taken into account by owners of domestic machinery, but which is growing in effect in proportion to the increase in the distribution of energy by public systems. It consists not merely in the competition with its product of the established cost or price of electric energy or steam, but in its liability to being rendered unproductive by a rearrangement of the requirements of the building it serves, whereby the combination of services with public electric or steam supplies, even at higher unit prices, may become less expensive, as a whole, than the continuance of the machinery in operation.

The effect of a recombination of machinery in isolated plants may become more comprehensive than any anticipated decay by physical deterioration or ordinary economic obsolescence. While it is true that the capital value of any machinery is depreciated fully fifty per cent. as soon as it has been put in service or use, and has thereby become "second-hand," it continues to have a usable value, to maintain which becomes the problem of its existence. But the extremely rapid developments of science soon supersede the commercial value of products of one appliance by systems or methods of different character. Thus hydraulic elevators have often withstood the introduction of electric operation, as they have proven safe and economical, and even the best modern types of electric elevators may fail to show much advantage when considered as a single element in a change. But when other processes of an economic nature are developed, which affect other apparatus in a plant, particularly where a complete change to electric operation is productive of a reduction of total expense, the hydraulic elevator loses its value. The reduction in the absorption of energy for lighting purposes has been continuous, and so has the reduction of electric energy used in electric elevator operation. More economical methods of heating buildings are being developed, and these eliminate heating at night, reduce the total expenditure, and thus discount the value of exhausted steam. Combined effects of this nature determine the obsolescence of an appliance. The maintenance of unnecessary expense in a whole plant is often chargeable to one element in its operation which in itself may be economically conducted.

The cost of combined services as against the narrow "unit" cost should be better understood

The costs of combined service, as against the narrow vision of costs of individual service or the still narrower "unit"-cost, are becoming better understood. Machinery planned and installed to provide services based on present or out-of-date conditions may not now be required, when modern and more economical methods are employed.

Depreciation is the financial expression of the combined effects of all of the foregoing processes, or the monetary result of deterioration and obsolescence. Provision for depreciation must be not only an insurance, within some given period, of the return of the capital which has been invested in machinery, but it must cover the probability of a change in its use. This insurance must cover indeterminable elements, just as in the case of the insurance of the life or health of human beings a "risk" must be covered of a more or less uncertain nature.

In the case of life and fire insurance recourse is had to methods which in time may come to be applied to machinery and may render the question of the amount of depreciation funds more exact than at present.

Averages of accumulated statistical facts are used to form a basis of probabilities of the extent of life, the probabilities of accident, the occurrence of disease, or the eventuality of fire.

In the case of machinery no such methods have been made available, nor has any system of combined insurance been organized. The insurance of machinery therefore falls upon the individual owner, and, like many other unpleasant duties, is as unwelcome as it is insistent.

But the necessity for providing for or insuring against depreciation is just as great as, and much more positive than, that for fire risk, which, after all, is a contingency that may be avoided; whereas the ultimate complete depreciation of machinery is positive, and is uncertain only in respect of time. The cautiousness of one investor may be contrasted with the recklessness of another in the extent of the provision that is made for this purpose. One man may set aside more than proves to be actually required,—in which case, however, he is not losing anything,—while another may set aside nothing, but is none the less carrying an eventual liability to meet the emergency when it ultimately arrives, and then often with funds not his own, or, in other words, by new borrowings. The depreciation will be there ready to meet him, sooner or later, and as surely as the grave.

There are two methods of providing for insurance of the life of machinery: either a book account may be set up, or cash may be invested in an accumulating and interest-bearing investment.

The former method involves a higher annual rate than the latter by the extent of compounded interest on the accumulations. The actual investment of such a fund, and the reinvestment of its interest earnings, is perhaps difficult of accomplishment under ordinary business conditions. The time may come when this form of insurance may become a part of the regular business of insurance; the owner paying a fixed annual sum, and the insuring company effecting the compounding of interest. This will not take place, however, until sufficient facts have been accumulated to form a basis for actuarial comparisons and averages of the insurer's risk. But in the meantime the facilities possessed by the large insuring companies for the reinvestment of funds would offer an opportunity for the lodgment with them of annual depreciation funds for the purpose of compounding the interest thereon. Such a system offers large opportunities for the security and advantage of invested capital in both directions.

Failure to make provision for depreciation from income uses up capital

The investment of money in a sinking fund, earning a low rate of interest, may not be necessary where the owner of machinery has any business or trade in which the money can be retained, and in which it will be productive of more profitable earnings. But even if that should be the situation, the establishment of a proper amount of depreciation is just as desirable. Under such circumstances the fund becomes a matter of careful accounting, and usually takes the form of a "straight-line" percentage of the original cost, and is not credited with compounded earnings of interest.

A large number of proprietors of real estate, however, are not in business or trade, and use the income from their property for their expenditures. They do not then fully perceive that, in failing to deduct or set aside from their income a suitable sum for depreciation, they are, in point of fact, using up their capital.

Annual percentages of the original cost required to be set aside, the interest on which, reinvested at several rates, will bring back the original investment within certain periods of years, can be found in the following summary, in which domestic machinery has been separated into characteristic classes, according to their probable limit of useful existence. Alongside each has been placed the necessary annual depreciation fund, first upon the book-entry or "straight-line" basis of an annual proportion of total invested cost each year, without interest. In three parallel columns are the annual percentages of the original cost which, if actually invested with compound interest at several rates of interest, will bring back the capital at the end of the term of years stated.

PROBABLE LIMIT OF USEFUL EXISTENCE OF APPARATUS, WITH CORRESPONDING ANNUAL DEPRECIATION FUND TO RETURN THE INVESTMENT

Term of useful existence indicates the rate of depreciation of machinery

Useful life in years	Class of apparatus	"Straight line."	Sinking fund to replace, compounded at		
		Per cent.	3 per cent.	4 per cent.	5 per cent.
10	High-speed, high-pressure reciprocating engines and machines on extremely variable loads	10	8.7	8.33	7.97
12	Fan-engines, high-speed rotary apparatus on large variations of loads, dynamos, motors, high-pressure engines, condensers; also exhaust heads, exposed galvanized ironwork, and hot-water drums	8.34	7	6.65	6.28
15	Moderate-speed reciprocating engines, medium-speed rotary apparatus, dynamos and motors; electric switches, wiring and connections	6.67	5.37	4.99	4.63
16	Elevators in regular use, laundry, kitchen, refrigerating, electric devices, and apparatus frequently reversed	6.24	4.96	4.58	4.22
17	Slow-speed reciprocating apparatus, such as pumps, elevator reversing gear, platform lifts	5.88	4.59	4.22	3.86
18	Drip and drain piping, cheaper class of pressure steam-boilers	5.55	4.27	3.9	3.55
20	Motor-driven pumps, compressors, and moderate-speed fans; sanitary piping, kitchen fixtures, refrigerating piping and valves	5	3.72	3.35	3.02
22	Dumbwaiters, switchboards, elevator gates, slow-speed elevator engines, shafting and bearings; slow-geared apparatus, elevators intermittently used; highest-class steam-boilers	4.54	3.27	2.92	2.6
24	Slowest-speed apparatus, apparatus intermittently used; exposed and unpainted vents and ducts	4.16	2.9	2.55	2.24
25 to 30	Interior drums and tanks, hot-water and pneumatic piping; pressure steam-piping and appliances; heating boilers used only part of the year; steel-plate stacks and smoke-ducts	4	2.74	2.4	2.09

CHAPTER XII

THE DEPRECIATION OF LABOR

Age and disability in a man are partly offset by increase in his experience

THE DEPRECIATION OF LABOR

THERE is a depreciation of human service, as well as of machinery. Very similar conditions apply to the employment of labor as to power machinery, modified, however, by the circumstance that intelligence and directing ability form part of the service of human beings. Thus, unlike machinery or animals, increasing age and physical disability of a man are offset to a certain extent by an increase in his experience and accumulation of knowledge. In this respect human labor has an advantage over every other kind of machine. In the employment of workmen their economic value may actually increase after a certain age, but the process involves a certain change in their conditions, or remodeling of circumstances so as to provide for a greater utilization of their mental capacity in proportion to their lessened physical energy. If a workman's employment be such as to call for no exercise of ingenuity or judgment other than that which has been required in his service in past years, then there is no opportunity of utilizing his developing mental capacity so as to offset his decreasing physical capacity, and the value of the man is depreciated to that extent. One industrial problem of the future will be so to utilize accumulated experience as to proportion it to, or substitute it for, the decrease of physical strength which accompanies age.

There is a phase of this subject which is receiving interested attention, not only on the part of the workers, but of their employers,—the subject of old age pensions, the value of which is not limited to humane considerations. The provision of such a system is a practical application of the principles of depreciation to the human machine, and may become justifiable on economic grounds. It is a matter of interest that the system has from this standpoint first been recognized and set in operation by the most modern and the most advanced of the developments of power utilization, namely, the electric light and power industry.

But a method of merely pensioning employes and rendering them idle on account of age or partial physical incapacity is archaic. Such a method may be applicable to military conditions, which, however, are fortunately no longer the ruling considerations in the industrial age in which we live.

Payment of a pension to an unoccupied employe, placed in that position merely by the condition of age, is more or less an economic waste, and is often productive of more harm than good to the apparent beneficiary. It is a well-known result of such a radical change in the conditions of a man's existence that it frequently brings about premature decease.

The treatment thus accorded to an employe is no better than that afforded some aged horse, turned out to overfeed itself to death by lack of accustomed exercise. A human being differs from animals or machinery in the retention in old age, or even during partial decrepitude, of intelligence and of accumulated experience, and oftentimes of superior skill. These are elements not possessed by the immature human machine, the young workman, whose accumulation of skill and knowledge is gained partly at the expense of the industry, and who is neither physically nor economically complete until the process of growth as well as the accumulation of experience has been accomplished.

There is a value thus added to human labor by its mere continued employment—that of increasing skill and experience.

Idle pensioners are an economic loss to an industry

This value is met to some extent by the difference in wages paid to the inexperienced and the experienced workman. The old method of apprenticeship, to which many of us must acknowledge considerable obligations, usually involved either a payment by the apprentice or a considerable period of labor without remuneration. These practices recognized the fact that the immature employe was under instruction at the expense of the employing business.

But the process of improvement does not altogether cease with the attainment of full physical growth and the knowledge of a trade sufficient to secure a standard rate of wages. The increasing experience and often superior skill of the elderly workman are often discounted by lessened health and energy, but a system of old age working-wage maintenance could provide the full continuance of his earnings, or even an increase thereof, which would represent part of his earlier efforts and earnings devoted to his advancing years.

Thus, the mere effect of age might be offset in man, as it could be in machinery, and the proper course for the application of a system of pensions is rather an age service system, by which a lessened amount of physical labor is required, and a greater utilization of the intelligence of the workman, with full maintenance of earnings. This may involve a change of situation or of duty. Idle pensioners are an economic loss to an industry, justifiable only in respect of entire incapacity of the employe. The payment of an equivalent or even greater amount for a reduced extent of labor would be an economic gain to the industry, and a practical benefit to the employe. It places the process out of the class of charity and puts the recipient on a self-respecting basis.

A well-founded system of old age insurance, in which, by an accumulation of diverted earnings both of the employe and the employing industry, the workman would be enabled to receive at a late period in life the benefit of an income, securing a less dependence on earnings and a larger proportion of leisure for rest and enjoyment, would, combined with methods of old age employment, secure to the old employe as full an income in old age as in the prime of life, and a reasonable utilization of his abilities for his own benefit and that of his industry.

In municipal operations the processes of the pension system are exaggerated and peculiarly lacking in economic advantage. As an employer, a municipality might be supposably in a better position than is the case in an ordinary industry to maintain the serviceable utilization of experience gained in its service. The modern municipality has a multiplicity of activities in which a transfer of opportunity for service can be made. The employes of governments and municipalities are not, as a rule, overworked or underpaid at any period, even that of immaturity and inexperience. The application of the military pension system, based merely on superannuation, is thus excessively wasteful. Systems of retaining a partial or contingent service by such pensioners, in the form of reserve service, might be organized, but are suited more to military or police organizations, and do not apply to industrial conditions or to ordinary employments in government or municipal service.

The mere fact that service during a certain period of time has been accomplished is no criterion of the incapacity of the employe.

Numerous instances of active and effective work by pensioners must be available to any inquiring person. In the City of New York the pension roll of the police force alone now exceeds two millions of dollars per year, paid to employes mainly by reason of a certain duration of service. Large numbers of such pensioners are earning wages in other active employment.

Public industrialism lags behind the commercial in this as in other directions.

Provision for the depreciation of an operative should, in order to be productive of advantage to the man and to his employing industry, take the form of decreased labor, accompanied by sufficient income derived from old age insurance to maintain the full earnings of the employe. This incentive to the work of the man is a source of advantage to the employing industry. The provision of an insurance for maintaining full earnings in old age will enable an employer to continue the partial employment of an operative after his full value has been discounted by age. Instead of a man being thrown out of employment entirely at a given period of his existence, his services can be continued to the extent of his ability beyond that point, and the world is that much richer as a result.

It is unnecessary to dilate on the incidental advantages of such a system in uniting the interests of the workman and his employer, and in decreasing the anxieties of the workman and of those dependent upon him. So far as the human machine is concerned, therefore, the same principles apply in general as in the case of economical appliances, with the essential difference of increasing intelligence, to which attention has been directed.

Employers are usually unacquainted with the causes of accidents

The operation of domestic machinery, involving the employment of labor, carries with it, of course, certain liabilities to accidental occurrences, which may result in injuries to the machines or to the men employed about them. Systems of insurance are available for the protection of the employer against such contingencies, over which he may have little or no means of control. Usually, also, such persons are unacquainted with the causes of accidents and the means of avoiding them.

Fire insurance upon machinery follows in cost the rate applicable to the class of building in which the machinery is installed. Thus a generating engine in a fire-proof building will be insured probably for eighty per cent. of its value, at a rate or percentage which is commensurate with the building in which it is located, and not related to its own value or its own liabilities to fire risk or its particular contribution to the risks of the building. In good "fire-proof" buildings in New York City the annual rate of premium is about fourteen cents per one hundred dollars of value of the machinery.

Where, however, the building is of a more readily destructible nature, the rate of insurance will rise substantially; and in the case of a manufacturing building in which trades of a dangerously combustible nature are carried on, the rate paid upon the machinery it contains may be as high as forty-five cents per annum, per one hundred dollars value, quite irrespective of the character of the machinery.

The risks to which machinery of this character are exposed are not always those to which the upper part of the building may be liable; for, placed as machinery usually is, in the lower part of buildings, the dangers due to fire may be increased by water flooding the lower portion of a building, and such flooding is peculiarly disadvantageous to electrical machinery of all kinds. The hazards of a building itself are not decreased by the installation of generating machinery in its interior, involving possible liabilities to accident. Close attention and careful upkeep may minimize these risks.

But the most important as well as the most uncertain of such liabilities is that of personal injury to operatives in machinery and boiler rooms, where the risk of accidental occurrences is naturally greater than would be the case under other circumstances. The contingencies in this respect are also of a nature which cannot wholly be covered by any system of insurance. The insurance against personal injury is usually limited to a certain sum by insuring companies, and any damages secured in a suit exceeding the sum insured for constitutes a liability on the part of the employer. Thus, for instance, in the case of an engineer slipping on an engine-room floor and becoming en-

Risks of accidents cannot be wholly covered by insurance

tangled in the moving fly-wheel, damages for ten thousand dollars were covered only to the extent of five thousand dollars in insurance, and out of the latter the expenses of defense of the suit were first deducted, leaving the larger share of the damages to be paid by the owner of the building.

Recent legislation in New York State has established a system of compensation for personal injuries which is applicable to domestic generating and steam machinery. This provides compensation for every accident, without consideration of many elements which tended to relieve the employer in the past. The system compels employers of such labor either to insure with the insuring companies or to deposit a capital sum as security for liabilities with the State authorities. So sweeping a system has naturally had the effect of raising the cost of insurance above the prior rate, making a substantial addition to the total cost of the employment of all labor. This insurance, as pointed out before, does not wholly eliminate the ultimate financial contingencies of serious accidents, nor does it cover the cost of the result of accident in the machinery. It is noticeable that many municipalities do not insure against this risk, and their only defense against excessive damages consists in an appeal to the courts.

The rate of premium is usually based on the wages paid. It is at present $1.10 per one hundred dollars of annual wages. To this annual sum employers add a special insurance against liability to other persons caused by the actions of their own employes. For this fifty cents per one hundred dollars of annual wages is paid.

Under the conditions obtaining prior to the establishment of the recent New York State insurance system, the contributory negligence of the injured employe or the negligent action of a fellow-employe was sufficient to bar the collection of damages. The situation in these regards is not at present entirely clear, but it is evident that the trend of the present and future legislation is towards casting the entire burden of support of injured employes, and of those dependent on them, upon the employing industry or interest, backed perhaps to some extent by the public credit. Litigation is not wholly avoided, since an injured person may sue for larger sums than are obtainable under a State compensation system.

Experience in the elucidation of the causes of accidents in and about machinery leads to the conclusion that the larger part are due to avoidable causes, and mostly to personal negligence. But such causes are not always evident, even to a competent employe, and still less so to a non-technical employer. Preventive means are often lacking because neither the immediate need for them nor the method of their application is readily apparent. The suggestions of the American Museum of Safety are worthy of consideration by the owner of any property in which machinery is installed.

Periodic inspection is desirable, by competent and experienced persons who are not employed regularly upon the machinery. Employes become accustomed to conditions of danger and habituated to risks which are not always apparent to them.

The duty of operatives is to protect machinery from accident and injury, but there is often no available means of protecting them from similar dangers which may be induced by their own unthinking actions.

The first person to suffer in a boiler-room or machinery space is usually an attendant. Means for their protection and escape in case of explosion or fracture should be a necessary part of the plan and equipment of every building in which machinery is installed.

Municipal regulations usually require a separate means of exit from a fire-room to the open air, but egress from an engine-room is rarely available except by some interior opening, which may not be accessible in an accident.

Employes become accustomed to risks not always apparent to them

The best precautions and safety appliances may fail in emergencies, unless employes are regularly instructed and drilled in their use. It is more difficult to safeguard the operator from the actions of machinery than it is to protect machinery from injury by the attendant.

CHAPTER XIII

OVERHEAD AND CONTINGENT COSTS

Disregard of indirect costs is an injustice to investment

OVERHEAD AND CONTINGENT COSTS

A NUMBER of elements enter into the cost of installation as well as the cost of operation of machinery which do not appear in current disbursements. They may be overlooked in making comparisons of the expense of operating steam or power generating machinery with the cost of equivalent service of a different character, or derived wholly or in part from public systems; and it is not surprising that this should often be the case, since those who own installations of domestic machinery are often little concerned in the financial factors governing monetary transactions. And in mixed plants there is a certain degree of difficulty in dividing up the cost of the operation of a number of machines, and in apportioning to each a due share of fixed expenses or of capital expenditures.

In careful accounting provision is always made for all contingent expenses and indirect costs. In any thorough investigation of expenses the ascertainment of the nature and extent of contingent costs or indirect expenses as well as of fixed charges becomes an important obligation. Disregard of such matters is an injustice to investment, and leads to confusion and loss. General supervision or management is one such matter. Scientific management has effected considerable economies in the operation of buildings, especially since building managers and engineers came in close touch within the membership of a national association. Some part of the cost of general management is necessitated by the supervision of machinery, and the high class of intelligence required for such additions to the profession of business management is properly remunerated by good salaries. The duties of management are substantially increased by the work of supervision and direction of labor, the purchase of supplies, directing repairs and providing materials. The cost of management rises in proportion to the number and extent of conveniences in buildings. Where it is placed in the hands of agents, its extent is determinable. As a percentage of gross rentals three per cent. is usually paid for residential buildings, and five per cent. for the management of business buildings.

The operation of manufacturing power on private premises involves some expense of time and attention in direction, superintendence, or supervision, particularly in the complexity of the problems of up-keep and the purchase of supplies and fuel. A portion, therefore, of the general expense is properly chargeable to the operation of mechanical apparatus of buildings. A steam or power plant, while it may be in the actual care of operatives, receives a certain proportion of the attentions or duties of the general management, and necessarily occupies to some extent the time of a manager, and therefore forms part of the services for which he is paid, or displaces attention otherwise devoted to other matters of value or profit. Similarly, the operation of a domestic plant of machinery involves some share of the cost of general bookkeeping. Possibly the personal attention of the owner of the property may be involved, though it may not be easy to determine the cost of the time and care devoted to such matters among other varied occupations, unless he should happen to devote his entire time to the matter, or should be a salaried official, such as the head of a corporation, the money value of whose time, together with the expense of his assistants and office, would be definitely determinable.

In the case of municipal operation of domestic machinery, an elective or appointed official, with the aid of a staff of appointed assistants, usually maintains the general direction and supervision of some department or bureau, including the accounting and disbursing of moneys for the operations of the departments under his care. The cost of the services thus rendered is a proper part or proportion of the cost of any work conducted by such a department, such as the operation of machinery.

The cost of management increases with the number and extent of conveniences in buildings

Space occupied by machinery involves capital cost and expense of maintenance. The commercial value of space which is occupied by machinery to the exclusion of other purposes is an item which rarely receives full consideration in the installation of domestic machinery. Power-plants, for instance, are frequently installed in basements or cellars, and sometimes in deep sub-basements, which have been excavated out of solid materials, involving relatively large investment for the space provided. The cost of constructing underground spaces is frequently in excess of that of other parts of the building, not only on account of the expense involved in removing material for its construction, but also because the heaviest part of the constructive materials of any building must be extended down through the lowest spaces. Thus, basements, and especially sub-basements, add to the length of the steel columns of a steel-framed building at their heaviest part, and also involve an extension of the thickest and costliest part of the walls. Sub-basements are frequently constructed on the assumption that they will cost little because deep foundations are required to be excavated; but they thus constitute a part of the burden of expense due to high construction. In themselves, they are often of dubious mercantile value. Yet any space occupied by machinery in a desirably located building may be of some value for commercial purposes, and if so, the plant may be displacing revenue to the extent that it could be dispensed with by some other method of operation or source of supply.

When basement spaces extend below the level of public sewers, they require waterproofing, and sometimes special drainage apparatus must be operated to keep them dry, or to drain away sewage collected at this low level. Artificial light to some extent is required, sometimes continuously, and artificial ventilation is not infrequently necessary. Access to such spaces may also involve the use of elevators. All these combine to create continuing expenses. There are also some indirect expenses. The entrances to basements sometimes involve interference with other parts of the building, and sidewalk openings and elevators often detract from street-frontage values. For any purpose to which such space may be put there is therefore some operating cost besides fixed charges upon the investment. These must be provided out of the rentals of other parts of the structure, if the space is occupied by machinery which does not earn any direct revenue.

If part of the space in a building be devoted to any specific internal purposes, such as heating apparatus or power-plant, then the interest which has to be paid upon the cost of constructing the space which is occupied by the apparatus is properly chargeable to, and reduces the value of, the service rendered by that apparatus. If the same service could be secured by other methods, or if the construction of the space could be otherwise avoided, or if the space could earn a rental, then the machinery is costing and is properly chargeable with the interest or with the obtainable rental. If the machinery can be dispensed with, even if the space must be constructed or has been constructed, then the space thus occupied may be released and utilized for other purposes. But even if it could not be rented, it is supported by the earnings of another part of the building which is rented.

In the case of a municipal or institutional building, the leasing of such a space for commercial purposes may not be

Space occupied by power-plants is maintained by the earnings of another part of the building

possible, but some utilizable value may remain if any commensurate use can be made of it. Thus, in the case of city-owned property the public purposes for which such buildings are designed usually involve an increasing demand for space for storage of public records. Indeed, it is frequently to be observed that spaces in commercial buildings are specially rented for the purposes of storage of municipal papers.

Basements, of course, vary in commercial value very largely on account of their locality, but more particularly by the convenience of the means of access provided. Spaces which are suited for restaurant purposes readily find tenants at prices from fifty cents to a dollar per square foot. Spaces which happen to be less advantageously located can be utilized for the storage of goods or materials for which their locality renders them suited. It must be admitted that some basements, and particularly sub-basements, do not and cannot ever produce enough rental to pay interest and depreciation upon their construction cost. Any deficiency in this respect is then made up by revenue obtained from some other part of the building.

Another point which is frequently lost sight of in the construction and the occupation of such spaces is the effect upon the building itself of businesses conducted therein. Odors from restaurants and heat from engine-rooms in underground spaces find their way up through the building, and may detract from its character and reduce its rentable value.

The ventilation of such confined spaces is usually a somewhat difficult problem, particularly where inadequate provisions have been made in the original design. The value of subsurface space is thereby discounted by loss in rental value in the building itself, due to odors created by the use of machinery.

Where basements are used for storage, the owners and tenants of the building above are generally unaware of any dangers which may be present in the contents of the space, and the building may be subjected to additional hazard, and insurance thereon may be increased. Steam-boilers and machinery installed under buildings may increase the rate of insurance on the whole building.

The cost per cubic foot of subsurface space must always be higher than that of any other part of a building because the space is less, relative to the constructed materials enclosing it. The removal of soil or rock under city conditions involves an initial expense of about two dollars to six dollars per cubic yard, or from seven to twenty cents per cubic foot of gross space. The cost of excavation for buildings varies by material, locality and season. In clean, hard soil twenty-five cents per cubic yard represents a minimum under favorable conditions of disposal. Inside a city ordinary soil may range from forty-five cents per cubic yard in summer to seventy-five cents in winter. Wet ground largely increases cost. An Omaha building cost one dollar and fifty cents per cubic yard for this reason. Where excavation is deep and haul for disposal is long, the cost may be as high as two dollars per cubic yard. Rock removal, even where conditions are favorable, costs several dollars per cubic yard. In a city such as Boston, for rock removed above grade, average bids have been three dollars and sixty cents per cubic yard, and for difficult work prices up to seven dollars per yard have been paid.

A basement or sub-basement space in a commercial building, say, twelve stories in height, in a plot 50 × 100 feet, would involve excavation and enclosing construction of 62,500 cubic feet.

The average cost of such a building may be taken at about thirty cents per cubic foot of gross contents, but the excavation alone might cost as much per cubic foot of material removed. The walls, steel columns and fireproofing reduce the available space to 45,752 cubic feet.

Part of the operating cost of any building applies to machinery spaces

The cost of this construction would be, with excavation at twenty cents per cubic yard, approximately	$21,300
Per cubic foot of gross construction	33 cents
Per cubic foot of available interior space	45 "
Or per square foot of available floor space	5 dollars
The interest, depreciation, and taxation, at ten per cent. on which would be	50 cents
And the cost of repairs, up-keep, lighting, heating, ventilating and drainage, easily	30 "

The upper floor spaces of loft buildings rent at rates from fifty to seventy cents per square foot, and the street level spaces from two dollars to three dollars per square foot, usually with the basement included. The basement would be a loss to the building, unless it should rent for a price per square foot, which would be probably in excess of that obtainable when the rates of rents for upper floors are as above mentioned.

There is a part of the operating cost of any building which applies to machinery spaces. Management, up-keep and taxes are as applicable thereto as to any other part of a building. The share of the costs of operation of a cellar space in a municipal building was found to be 4.46 per cent. of the total operating costs and fixed charges. The floor space occupied by machinery is properly chargeable with its share of the operating cost of the building, just as much as would be the case if it were rented out to a tenant.

In the City of New York conservative public opinion has been adverse to the establishment of municipal schemes of public service, but such considerations have had little weight in limiting the investment of public funds in machinery for the production of heat, light and energy in public buildings, and in the construction of most institutional buildings of importance the installation of a large amount of machinery has been made, necessarily involving the accompaniment of a considerable amount of labor, and generally regardless of the financial limitations on the value of the result.

Such installations have always been relatively expensive, occupying also expensively constructed interior space.

The space occupied by boilers and their auxiliary appurtenances is about three square feet per horse-power. In power-plants the space occupied by electric engines and generators, switchboard, etc., is from three and one-half to five square feet per kilowatt of installed capacity. The capital cost of the space thus occupied in a basement may be from four to six dollars per square foot, adding approximately to the cost of the machinery fifteen dollars per boiler horse-power and twenty dollars per kilowatt. Boiler-plants cost from twelve to eighteen dollars per horse-power, and electric generating plants from fifteen to thirty dollars per kilowatt of capacity. So the cost of space may add from fifty to one hundred per cent. to the cost of the apparatus.

Of a combined plant, including elevator pumps, the proportions of total space occupied are:

Boilers, coal space and auxiliaries	48	per cent.
Electrical engines and generators and switchboard	29	“ “
Elevator plant and tanks	12	“ “
Water tanks, house pumps, sewage pumps and engineers' storage spaces	11	“ “

The share of the capital cost of a building which is involved in its mechanical equipment is substantial. It ranges from nine per cent. to fifteen per cent. of the entire cost. The addition of steam and electric power generating apparatus will increase the cost of the building by from seven to eleven per cent.

In ascertaining the commercial value of the operation of power machinery, it should properly be charged with taxes upon its original proportion of the total assessed valuation of the building.

The cost of space occupied may add a hundred per cent. to the cost of machinery

The taxation of a building is chargeable to machinery installed therein, in proportion to its capital value.

The actual value of machinery, however, depreciates more rapidly than the building which houses it. So the assessable value of the whole property is really reduced thereby. If, therefore, there is any increment of the value of land or building, it is offset to some extent by the depreciation of the machinery. But these considerations are not recognized by taxing authorities, so the full rate of taxation is really paid on the original value of machinery, long after that value has fallen below the original assessed valuation.

Taxes must be paid by private power machinery because the production by a private plant of a product which is purchasable from a public system displaces an equivalent value on which taxes otherwise would be paid. Taxes paid to a municipality by public service corporations bear a relation to the product distributed and sold by them. Their revenues act as a reduction of the taxation which is otherwise to be borne by private properties. The purchase of part of a public service carries with it a contribution to public funds.

Public corporations which exercise the rights of supply by the use of the public streets usually contribute to the city revenue by several forms of taxation. They pay direct taxes upon their real estate and special taxes upon franchise rights, the latter of which vary in certain cases in respect of the profits made by the sales, and sometimes by the gross business done.

It is a remarkable fact not widely known or appreciated that the amount paid in taxes by electrical supply corporations is frequently greater than the value of the fuel used to create the energy supplied. The cost of energy in central stations is made up of three main elements, labor, fuel and taxes, and of these the last is frequently the largest single item. In discussing, therefore, the charges which are made or the prices paid for distributed energy, it should always be borne in mind that the purchaser of energy is really paying in part an addition to the cost which has been created by the general public, but which when paid relieves himself as well as other taxpayers, the result being that for the convenience afforded a proportionate part of the general burden of taxation is borne by the person enjoying the advantage. This is not criticized as an undesirable situation, but it is one of the underlying conditions to be recognized in considering the comparative value of the production of energy by private apparatus rather than the production of it by public franchise.

In the City of New York there are several systems of public service which are large contributors to the tax income of the city. Among these the electrical corporations take a large share, one having paid during five years a total exceeding five millions of dollars.

The amount which is paid, while it has been increasing in total, varies in its relation to the electrical output of a public system because of changes taking place in the latter, but the average proportion has been from two-tenths to three-tenths of a cent per kilowatt-hour.

While the acquisition of these contributions to the city revenues thus reduces the total taxation paid by the citizens, the effect, being indirect, is not a matter of large concern to private owners of machinery. But it has a particularly direct bearing on municipal operation of machinery, since if the city operates an apparatus when it could purchase its output from its enfranchised partners, it loses the taxes which would have been derivable from the increased services of the corporations.

In the case of a district steam company, a city may also lose a cash return for the water that would be used to generate the steam used in purchased services. In New York City water is paid for at the rate of one dollar per thousand cubic feet, and one company's contribution to the revenues exceeds forty thousand dollars a year, and has aggregated nearly a million dollars during its term of existence.

Taxes paid by some public systems exceed the value of the fuel they consume

CHAPTER XIV

POWER IN INSTITUTIONAL AND MUNICIPAL BUILDINGS

Provision for adequate depreciation is seldom recognized in municipal or institutional investments

POWER IN INSTITUTIONAL AND MUNICIPAL BUILDINGS

THE provision of a proper fund for the return of money invested in power and other machinery is recognized by commercial investors, but is not equally admitted in municipal or institutional investments. The propriety of such a course is none the less apparent where the capital investment has been effected by funds donated for the purpose, even if the capital does not carry any interest charge.

Institutional buildings are usually free from taxation, and their capital investment is frequently derived from charitable gifts or from public funds. Buildings such as the numerous establishments of an associational character and kindred organizations are often erected out of funds provided by voluntary subscription.

Steam and power plants in institutional and educational buildings are thus usually provided by funds of this character.

Funds derived from such sources when sunk in power machinery may appear to be free from any charges for replacement or for interest, as they are for taxation. But the process of operating a domestic plant is not income-producing, its only financial return being an assumable difference between its total cost and that of some other method or system of equivalent service. Thus there is in such buildings no revenue available to meet such charges, so they are customarily ignored. So far as interest is concerned, this may be justified, yet when the life of a plant is ended there is no means, except by another appeal to charity, for securing its replacement. Such institutions, further, frequently fail to secure sufficient income to meet all outgoing expenses, and any annual deficiency must be made up by soliciting donations. The installation of power machinery is therefore accompanied by special disadvantages, because the original capital invested therein is diverted from some other part of the work of the organization where it might increase the operations or perhaps even increase the income. Thus, the assumable or estimated reduction of annual operating costs which may be effected by a power-plant (which is at any time only an estimate, and may be effecting no reduction at all) inures to the benefit of a different charitable subscriber, and not to that of the donor of the funds for the building and the plant. Moreover, if the donor's money which is sunk in a plant were invested in the construction of additional income-providing accommodation, such as, for instance, additional cubicles or bedrooms in an association building, the investment might produce better and certainly more definite results. Or, as in the case of a general fund for a number of buildings, it is probable that the amount diverted into machinery might provide some other desirable additional buildings.

Thus, for instance, bedrooms in association buildings are sources of revenue, and are usually in much demand. They rent at rates of from two and a half to three dollars per week. The cost of construction is about five hundred dollars per room, the income derivable from which may be from one hundred to three hundred dollars per annum. The expenditure of money upon power machinery, therefore, may be a very poor investment compared with the construction of additional revenue-earning space of this character.

The capital cost of a power-plant in an institutional building having fifty bedrooms per floor is $18,000, not including the cost of the space it occupies. The same expenditure would add thirty-six additional bedrooms, renting at $10,800 per annum.

Unnecessary investment in machinery is a misuse of public or charitable funds

The operation of the power-plant could not possibly effect such a saving.

The trustees of charitable funds therefore appear to be taking considerable chances when investing in short-lived machinery, unless the necessity for such machinery is evidenced by the absence of any other possible means of producing equivalent results. Especially is this the case where reductions in the cost of public services, such as steam or electricity, have taken effect after a plant has been installed. The charitable or public fund which has been invested in such a plant is then entirely lost to the purpose for which it was donated, even if the cost of operation should show a result equal to any other method of operation without the plant. Money invested in a building may have a useful effect during half a century's existence, but money sunk in engines, pumps and boilers cannot outlive the useful life of such appliances; and in the absence of any direct income, as no depreciation or renewal fund can be provided, the effect of the donation, so far as it may be expended in machinery, is lost in a few years of operation of the apparatus. Therefore the fact that institutions cannot provide for interest or depreciation upon such expenditures of their donors' capital is not in favor of, but is adverse to, the installation of machinery.

The same principles apply indirectly to commercial circumstances. If other, equally fruitful purposes can be served by the capital, then the investment in machinery is of less value because it is shorter-lived and less certain of results.

In a commercial building of eleven stories, 50 × 90, the investment in a power-generating plant would be at least twelve thousand dollars, which, if expended in building construction, would provide about four thousand square feet of rentable area, the income from which, at sixty cents per square foot, would be about two thousand four hundred dollars.

In order to present any commercial value, the operation of such a plant must show a larger return, by a direct saving in the cost of operation, over any competing system or service which would involve no capital outlay. It will not suffice to show an equal or less amount, because the tendency of improvement will be towards a reduction in the cost of public services, for which a substantial margin should be allowed.

Supposing, further, that the absence of the plant would release for renting purposes the space it occupies, then the plant, to be of advantage, must demonstrate savings in excess of the rent of which the building is thus deprived.

The construction of spaces unutilizable for any other purpose than machinery does not relieve this situation, since it has involved the building in a fixed annual expense without any direct return thereon.

Capital, once sunk in machinery, cannot be recovered unless its product be salable at a profit.

At the time of the purchase and installation of machinery for any particular purpose, the investment and the interest which would be payable upon the capital are a consideration which enters directly into the comparison of the cost of the services to be rendered by the plant, as against those purchasable elsewhere. But after the investment has once been made, and the capital has been sunk in the plant, the removal of the latter or the cessation of its operation does not relieve the proprietor of the burden of continued payment of the interest, or of amortization of the principal. The loss of the capital has been made, and the only partial return which can be secured is by the sale, generally at a sacrifice, of the used apparatus. Thus the interest and any sinking fund continue, and are required to be saved by lessened costs to that extent. This unfortunate situation of continuing loss sometimes precludes any relief by a change of method. It is the result of a failure to count the cost at the time of the original investment in machinery.

A plant has no value unless it will afford better results than any other method of equal service

In making such investments, whether on municipal or private accounts, the question should be fully faced, and due regard should be given not only to the rate of interest which may have to be paid for money loaned or invested, but to the value of the same money expended in other directions. As the value of money increases with time, the tying up of capital may prevent its use at increasingly remunerative returns.

Such considerations are often set aside at the time when the decision to purchase machinery is made, as some owners of property regard a large building as being to some extent incomplete unless it be provided with more or less machinery for the production of its own needs.

Some mortgagees and lenders of money on improved real estate seem to labor under the impression that by insisting upon the installation of machinery in a building they are securing additional advantage to a building loan or mortgage. In this respect they lose sight of the fact that the life of all machinery is much less than that of the building which houses it, and that as a form of security the value of any machinery is discounted by its first day of usage to the extent of fully fifty per cent. The only value of any machinery in a sale of a building lies in its capability of reducing the expense of operating the building, after the cost of replacement and the cost of the space it occupies have been fully provided for. If any other service, system or method will afford better results, then the plant has not only no value, but is a detriment to the purchaser, and may constitute a reduction of the commercial value of the property. If there be no other possible means of providing for the product of a plant, it becomes an unavoidable expense deducted from the building's income.

Since the price paid for commercial property is generally based on the total results, of which the machinery's operation forms a part, generating machinery purchased with a building has only that capital value which is represented by its net contribution to the economy of operation of the building.

Where the investment in such a direction has been made, it cannot be recovered by any means except to the extent to which the sale of disused machinery will repay the original investment. This machinery has generally no more than a scrap value after some period of use, and even this value is frequently discounted by the difficulties attendant upon the removal of machinery from confined spaces, and by the fact that it becomes antiquated. Unlike a piece of land, or even a building, which may have a chance of an enhancement of value, there is no possibility of anything but depreciation in the value of machinery. Careful investors might hesitate to lend money on the full value of such a form of security if fully informed upon the subject.

The methods under which public funds are provided for such capital investments are such as could not be economically practised by a private capitalist or a business corporation. The investment of public moneys in a building is effected by borrowing, upon the credit of the community, from exterior investors. These indebtednesses are usually and properly paid off by the accumulation of a sinking fund, a process of gradual accumulation, from the pockets of the taxpayers, of the capital amount borrowed, upon which in the meantime interest has annually been paid.

Municipal financial methods usually extend the life of issue of bonds to periods of twenty-five, thirty, forty, and even fifty years, in the effort to reduce the annual burden of the taxpayers in the repayment of the principal. But if the object upon which the expenditure has been made should be of such a character that its useful period of existence is less than that of the currency of the bond, it then comes about that such money, if invested in machinery, may have to be replaced by a second issue of bonds before the first one is paid off.

Unlike land or buildings, there is no possibility of increment in the value of machinery

This is actually the situation existing to-day in connection with some investments by the City of New York in power machinery, the life of which is limited even under the best conditions of maintenance and operation. Such conditions do not exist under municipal management, and the absence of care has corresponding effects in shortening the life of apparatus.

It is a noticeable and contributory condition of our municipal system that the very methods by which protection is sought over the expenditure of public moneys by departmental officials contribute to losses due to neglect of machinery. Necessary repairs are usually postponed until they accumulate to an extent sufficient to make it worth while to advertise the work on a competitive basis. Departmental budgets, which are one of the devices of modern municipal methods, cannot always anticipate the need of repair or restoration, which thus goes neglected, and often becomes more serious and expensive as time proceeds.

The annual cost of a municipal plant involves a continuing amount per annum for interest for a fixed period, and the abandonment of its operation or the wearing out of the plant would not remove this burden, which must be continuously carried until the maturity of the bonds or stock from which the borrowed capital was obtained. The interest alone upon a plant, which will have been paid by the time a fifty-year bond has matured, will at four per cent. be twice the original value of the plant; but it must be noted that long prior to such a late maturity of the bonds, the useful life of any plant will have come to an end, and replacement, in whole or in great part, will have had to be effected. It will then come about, after, at most, about half the period has passed, that there will be a continued payment of interest in respect of an investment, the subject of which has passed out of existence.

The acquisition of appliances having a short period of useful existence, by the issuance of long-term bonds, is one of the fundamental errors which afflict municipal finances. The purchase of any machinery for city purposes should be based upon bond issues extending over no longer period than the probable term of economic existence of the appliances, which, in view of the march of modern improvements, should not much exceed fifteen years. When the time of replacement arrives a short-term bond issue will have been paid off, and a new loan may then be made.

As regards this supersession of municipal machinery there should be the provision and actual investment of proportionate depreciation funds, similar to sinking funds, which shall, within a reasonable length of time, provide for the replacement of the apparatus by other, newer appliances, without the obligation of borrowing new capital for the purpose. This is quite independent of any sinking fund for the repayment of the original borrowed capital. In the case of city-owned machinery, it has been claimed by city officials that the operation of a sinking fund which has the effect of gradually repaying, out of direct taxes, the principal sum borrowed affords a full depreciation. This is not the case, even as regards investments in buildings or in public structures such as bridges, the life of which exceeds the period of the bond, but it is certainly far from being true in respect of machinery, the life of which terminates long before the completion of the process of amortization of long-term bonds. The purpose of the machinery, also, is purely competitive where public services exist, and the machinery should therefore earn its own replacement by the saving it effects, if it can do so.

If a bond be issued for thirty years upon machinery, the life of which is but fifteen years, then provision must be made to meet the useless interest which continues to be paid after the machine has gone out of existence. In such an instance, unless

Where public services exist, the purpose of machinery is purely competitive

there are to be two loans outstanding on one machine, one-half of the total amount of interest to be paid upon the bonds representing the original value of the machinery must be earned by a sinking fund. Interest on one hundred thousand dollars expended in machinery raised by a thirty-year bond at three and one-half per cent. will amount to a total of one hundred and five thousand dollars. If the useful life of the machinery terminates at fifteen years, then one-half of one hundred and five thousand dollars, or $52,500, represents added financial loss, or financial loss which should have been provided against during the fifteen years of its existence. And let it be noted that this is merely repayment of capital. It does not provide any funds for the replacement of the worn-out apparatus.

It is needless to say that under common systems of municipal finances no such provisions are made. Our methods in this direction are in marked contrast to those which are followed by careful systems in vogue in some municipal operations in Europe, where every element that should properly enter into consideration is brought into the accounts of municipal trading, which is charged even with its share of municipal contributions to charities and uplift work.

The attention of public authorities has been only recently devoted to a phase of this subject which has long been known to outside observers, namely, the issuance of revenue bonds for the repaving of streets, which, like machinery, have a very limited term of useful existence. In certain instances several issues of bonds, all bearing interest, are all current at the same time in respect of successive repavings of a certain street. It is to be hoped that in this respect more enlightened and cautious methods will be applied to the investments which may be made by the city upon such objects, but they should be applied particularly upon the purchase of machinery.

CHAPTER XV

INDIRECT OWNERSHIP AND OPERATION

Real estate ownership should not be involved in the business of operating machinery

INDIRECT OWNERSHIP AND OPERATION

OWNERS of buildings sometimes delegate to contractors the operation of machinery on their premises. There are concerns or organizations which make a business of operating heating and power plants with considerable effectiveness. The owner of a building is a gainer by such an arrangement if the effect is to reduce his total annual outlay upon the service or output of the installed apparatus.

Contractors for this character of service are able to compete with the individual management of machinery because their operations are conducted on commercially economical lines. They are able to purchase fuel and other materials on a larger scale, as their business includes a number of plants. They economize not only in the use of these materials, but in the extent of labor required. They are able to engage the services of well-informed and even expert operatives, and by their aid can secure higher efficiency and better economy in the performance of each individual apparatus. In fact, the whole operation is business to them, and is not an appendage of a larger occupation, as is the case where machinery is managed by the owner of real estate.

In some cities municipal regulations permit of their uniting the steam and electric services of contiguous buildings, so as to reduce the use of unnecessary machinery, combine the demands, and centralize the services of employes upon larger output, thus reducing the labor cost of individual operations.

These contractors have relieved the ownership of real estate of much direct cost, and they have a wide field of usefulness.

But even with the reduced total costs effected by this system, comparison should be made from time to time of the effect of changes in the combination of services, and the substitution of purchased service where it is available.

The operation of a contracted service may be economical, but the extent may be based on wasteful usages. The best use of a contracted service would seem to be made by engaging the expert assistance of the operator in reducing wastages of use as well as waste in production, a process which has been very successfully applied in certain instances.

It is not good business to contract for a loose quantity, such as the total heating or the total lighting of a building, without regard to economy in the use of steam or energy. These may be maintained at a wasteful or unnecessary extent, and while the contractor is straining at economy in production costs for his own benefit, the proprietor of the premises is paying a price, based on stereotyped conditions, which may be much larger than it need be.

The employes of buildings do not always regard with favor the introduction of contract management. The economy effected often appears to them as a reflection on their own ability. They are sometimes hostile to the extent of endeavoring to defeat the efforts of the economic contractor by maintaining or increasing the usage of heat or energy.

A method of securing a rather lucrative line of business is offered by some contractors, which is of dubious value. It consists in a profit-sharing arrangement in which the difference between the cost under the contractor's method of operation and a prior existing and generally wasteful condition is to be divided. Another method, employed where public service is in operation, is to estimate upon a reduction in cost by the use of generating machinery, and then to offer to supply that machinery on deferred terms of payment, or sometimes even on a payment of a part of the price, in consideration of a share of an assumed difference in annual operating cost for a term of years.

The sale of steam and power by landlords is often productive of disputes

If the price of the machinery be made sufficiently high, such an arrangement may enable a contractor to install the plant with very little capital investment on his part. The owner is usually required in such arrangements to pay interest on the total price, which thus more than covers the interest on the actual cost of the machines. The difference assumed to be secured in the operating cost of the plant as compared with prior conditions is often more apparent than real, but the owner of the property has to pay a share to that extent for a period of years, which thus returns an easy profit to the contractor on the price of the machines.

Speciously attractive propositions of this character rarely bear close investigation, as they almost invariably have some concealed elements to the contractor's advantage and to the owner's ultimate disadvantage. In any case, they have the effect of tying the owner's hands by a contract for a term of years, and of leaving him in possession of machinery which may by that time be out of date, or may be discounted in value by reductions in the cost of public service, or by newer methods of accomplishing the services of the premises.

The operation of isolated plants is sometimes made self-sustaining by the sale of their product.

The proprietors of some buildings have established therein a system of charging their tenants for supplies of electricity, steam, water and refrigeration. The propriety of charging for such services cannot be questioned. If universally applied, the process would tend to reduce rentals, to encourage thrift, and to relieve real estate. But where it is carried on as a means of reducing the cost of operating a private plant it is of dubious value. To set up an expensive process, and then proceed to reduce its expense by selling part of it, is commercially justifiable where the market for the commodity is open. But in a building the market can never be increased beyond the full quota of tenants, and every vacancy restricts the market and throws a larger share of the burden back on the producer.

The sale of steam and power in this manner has been productive of innumerable disputes and litigation between landlord and tenant. The service afforded by owners is often abused by tenants by excessive use and wastage. In one case which was fought out in court the sudden and excessive demands of a tenant completely ruined a steam-boiler and involved the owner in a large expense for installing new and larger apparatus. Individual tenants demanding overtime and night service involves the owner in the operation of machinery under disadvantageous and costly conditions.

For what profit there may be in it, the process can be as well pursued, and with much less risk and liability to dispute, by the purchase of electric or steam service in quantity, and its resale to tenants—a process rather widely adopted in New York City. The owner, under such circumstances, purchases the entire supply for the building at a reduced rate, and charges the tenants for their usages at a retail rate. This may work well where proper means for measurement of services can be provided. Until quite recently this system was facilitated by the free supply of sub-meters, or tenants' meters, by electric power companies, who maintained these meters free of charge and sometimes even indexed them, rendered bills to tenants and collected the amounts due. Such accommodations eventually became burdensome to the companies, and are no longer afforded gratuitously. The owner of property must now purchase or lease meters for the purpose of measuring the usage of his tenants. As this is a domestic operation, the present arrangement appears to have propriety on its side, though the owners of real estate naturally chafe under the deprivation of the gratuity they have

Machinery leased with buildings is subject to divergent interests

long enjoyed. The situation has grown out of the not unnatural desire of the owners of real estate to secure some better returns upon property than can be obtained by rentals only. But the policy of conducting more than one business at a time is uncertain, and the closer the shoemaker sticks to his last, the less uncertainties he is likely to encounter.

The owners of some unimproved property have been confronted with the problem of the purchase of isolated plant machinery for the use of tenants for whom they have constructed buildings upon long leases. This situation has curious complications. The landlord has no interest whatever in the isolated plant's purpose or economy, but is concerned only in the initial outlay. In the case of a long lease he has no prospective interest in the plant at all, as it will, at the end of twenty-one or twenty-five years, be out of date, if not out of service.

The tenant, on the other hand, has a lively interest in securing the plant, which costs him no direct outlay of capital, and may be something to the good if it can be made to pay. Though the capital cost of the plant is really paid for in the rentals, it does not involve immediate payment. The tenant is only concerned with its economy, so there is usually quite a fight on his part to secure the most expensive plant, while the landlord generally endeavors to get off with the least expenditure of capital.

In most cases the result is a compromise, and is somewhat to the disadvantage of both parties. During the lease a tenant is careful of a plant because it is to his interest to make it last to the end of the lease, but he is rarely disposed to spend capital for renewals or replacements, because he will not get the full value of the investment during the term of the lease. The unfortunate plant thus is much in the position of the child of divorced parents. On either hand it has an ownership of divergent interest. The lessee knowingly pays interest in part of the rent, but rarely recognizes that the capital cost of the plant is also covered in the rent. In a large commercial building, a lease for which was already closed, provision was made for a steam and electric power generating plant. Upon consideration of the subject as above presented, the landlord and tenant appraised the value of the proposed plant, and both found it to their advantage to abandon it in favor of public electrical service. The owner was saved the investment, and thus was willing to reduce the rental to the extent of the annual interest and depreciation thereon. The tenant secured a lower rental and found a value in the space required for the machinery, which could be utilized to commercial advantage, and also avoided liability for up-keep, renewal and any replacement of apparatus.

Many hotels are leased with power-plants. The results are much as have been described. The plants involve the cost of up-keep and renewal, often requiring extensive changes; but these are denied because the lessee cannot be sure of reaping the full benefit of the outlay. Even where a direct saving may be effected in operating cost by an outlay of capital, the lessee of a hotel will prefer to invest the amount for business purposes bringing in more direct and perhaps more remunerative results.

Lessees are, of course, the apparent sufferers, as their profits are reduced by undue or unnecessary costs in the fire-room and engine-room. But at the end of the lease the landlord is also confronted with loss in a worn-out plant, often requiring almost entire reconstruction. The depreciation included in the rental has rarely been set aside, so that the cost of renewal involves a fresh outlay of capital. Where tenants would find it to their advantage to abandon the use of a leased plant, as the apparatus cannot be removed from the premises, the advantage and value of the use of the space are lost. It thus comes about that the leasing of machinery, under the conditions surrounding it, is of doubtful value to both landlord and tenant.

The avoidance of risk and of unnecessary investment in machinery increases the security of rea estate

There are some indirect liabilities which should be considered in connection with the subject of selling the output of heat and power-plants.

The undertaking, on the part of a landlord, of the supply of any continuous service, whether gratuitous or not, to a tenant, involves responsibility for its continuance. The failure or deficiency of a service may, as it often has done, bring about a demand upon the landlord for damages for direct or indirect injury inflicted on the business of the tenant. A number of cases have been brought before the courts, in which tenants have succeeded in breaking leases on the ground of failure on the part of their landlords to provide sufficient heat in cold weather. Failure of electric supply in the case of loft and manufacturing buildings has been productive of many disputes. Tenants of such buildings sometimes demand a service beyond working-hours in order to carry on their trade. The cost of such service to a single tenant is excessive.

These responsibilities cannot be fully foreseen, and therefore should be considered as contingent upon any system of the manufacture of heat and energy for sale to tenants even at an apparent profit.

The business of selling energy, steam or refrigeration to tenants is, moreover, of insecure character under city conditions, because whatever may be the value of the product or service, it is liable to be reduced by the competition at declining prices of a public supply.

In many instances where an agreement has been made, as is usually the case, that the tenant shall pay for the service supplied, at prices not exceeding the prevailing prices of a public supply, the proprietor of a building has found his income reduced. Any reduction in public rates, therefore, disturbs the conditions of revenue in buildings where these arrangements are in force. A recent reduction in electric rates cut more than twenty per cent. off the revenue of those landlords who were selling to their tenants electric energy generated by isolated plants. The commercial value of the output of every isolated plant in the area was reduced by this decline in the cost of public service.

Telephone service in apartment buildings is conducted, in New York especially, under onerous conditions. The proprietor must contract for a trunk-line connection and a switchboard, must provide attendance, install extension connections at his own cost, and pay rent for each tenant's telephone. A contract is then made for a wholesale number of calls at low rates; but the value of a message is fixed by the prevailing rates on general public service, and the owner is usually unable to charge more than the general rate of five cents per message. In this price must therefore be covered the costs of operation and of the collection of the bills. All deficiencies in collections, and the cost of all false and incorrect calls and toll messages and misuse of the service, fall upon the owner of the property.

The result has been a very wide-spread and serious loss to real estate. While this telephone situation has features peculiar to itself, the experience thus gained has been so manifest and unfortunate that it is very illustrative of the doubtful value of other business operations by the owners of real estate, such as the manufacture and sale of heat and power.

The desirability of the avoidance of risk and responsibility appears to apply to all such services as light, heat, power, water, ice and refrigeration, wherever these can be secured from any public source and the tenant can be brought into direct contractual relations with the supplying agency.

The reduction of any unnecessary expense, and the elimination of any risk or contingent source of loss, are advantages to the security and attractiveness of real estate as an investment, and constitute additions to its capital value.

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